SCS
NATIONAL
ENGINEERING
HANDBOOK

SECTION 15

IRRIGATION

Chapter 4
Border Irrigation

SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

The Soil Conservation Service National Engineering Handbook is intended primarily for Soil Conservation Service engineers. It also contains information useful to engineers in related fields.

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Border Irrigation, Chapter 4, Section 15 (Irrigation), describes the three kinds of border irrigation--level, graded, and guide--and the factors that determine their respective use, e.g., topography, soil, and water supply. The advantages, limitations, and design of each of these three kinds of border irrigation as well as general layout and construction considerations are discussed.

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SCS NATIONAL ENGINEERING HANDBOOK

SECTION 15

IRRIGATION

CHAPTER 4--BORDER IRRIGATION

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NOMENCLATURE

A = Area (square feet)

a = Intercept of accumulated intake at unit time

b = Exponent of time in intake equation

c = Constant in intake equation

C_d = Flow depth conversion factor

C_t = Recession-lag time conversion factor

d_1 = Depth of flow at head of run (feet)

d_a = Average depth of flow (feet)

d_n = Normal depth of flow (feet)

E = Field application efficiency (percent)

F = Accumulated intake (inches)

F_a = Average depth of intake (inches)

F_g = Gross depth of application (inches)

F_n = Net depth of application (inches)

I_F = Intake family

K = Site factor

L = Border length (feet)

L_e = Length extension with end blocks (feet)

L_t = Length of advance (feet)

n = Roughness coefficient in the Manning equation

Q = Irrigation stream for a border strip (cubic feet per second)

Q_i = Intake rate during the recession-lag period (cubic feet per second)

Q_o = Flow of water down the border strip (cubic feet per second)

Q_u = Irrigation stream per foot of strip width (cubic feet per second)

q = Unit irrigation stream (cfs per 100 square feet)

r = Hydraulic radius

r_i = Intake factor for runoff prediction

r_n = Roughness factor for runoff prediction

s_1 = Slope of water surface or hydraulic slope (feet per foot)

s_i = Hydraulic grade (feet per foot)

s_o = Slope of border strip or irrigation slope (feet per foot)

T_a = Time of application (minutes)

T_L = Recession-lag time (minutes)

T_n = Time required for the net depth of application (F_n) to infiltrate the soil (minutes)

T_o = Intake opportunity time (minutes)

T_t = Time of advance (minutes)

V = Volume of water on border strip (cubic feet)

W = Border strip width (feet)

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SECTION 15

IRRIGATION

CHAPTER 4. BORDER IRRIGATION

Description

Border irrigation is a method of controlled surface flooding. The field to be irrigated is divided into strips by parallel dikes or border ridges, and each strip is irrigated separately. Water is introduced at one end and progressively covers the entire strip. Three different kinds of border irrigation--level, graded, and guide--are used depending on topography, soil, water supply, and other factors. Each kind has features that are advantageous under some circumstances and disadvantageous under others. In planning an irrigation system for a farm and selecting a method of applying water to the soil, the advantages and limitations of each of the three kinds of border irrigation must be considered carefully. Level, graded, and guide border irrigation are discussed in detail later in this chapter.

Adaptability

Border irrigation is suited to all crops that are not damaged by inundation for short periods. It can be used with almost any crop if site conditions are such that the needed degree of water control can be obtained. It can be used on nearly all irrigable soils but is best suited to soils whose intake rates are neither extremely low nor extremely high.

Layout Considerations

In addition to the limits on design imposed by hydraulic factors (discussed later in this chapter for each of the three kinds of border irrigation), design may be limited by practical layout and construction considerations. The empirical limits suggested by these considerations are not precise, mandatory requirements, but they are guides for design. They should be exceeded only with great caution.

Border Strip Width

Border strip widths suitable for any particular field depend on (1) size of the available irrigating stream, (2) amount of cross slope that must

be removed, (3) kind of equipment used, and (4) accuracy of land leveling as related to the normal depth of flow expected. The border strips must be wide enough to permit efficient operation of farm equipment. Mowers and rakes, for example, can be operated where there is a small amount of overlap on passes. Other equipment such as plows, seeders, and cultivators requires a definite width for each pass. The border strip must be wide enough to accommodate at least one pass of a plow, seeder, cultivator, etc., but it is desirable for the strip to be wide enough for an even number of passes.

A width of about 15 feet is the practical minimum for each strip on hay and grain fields. Narrower strips are satisfactory for pastures. For row crops grown on level border strips, the strips usually must be wide enough to allow for at least two passes with four-row equipment.

Maximum width is influenced largely by the difficulties in keeping water spread over the entire width of a strip. Under normal construction, wide border strips are expected to have greater differences in cross slope elevation than narrower strips. As flow depth decreases because of increased slope, minor surface irregularities in the border strip may cause incomplete water coverage. For this reason, the border strip width must be reduced as irrigation grade increases (see table 4-1).

Table 4-1.--Recommended maximum border strip width

Irrigation grade	Maximum strip width
Feet per foot	Feet
Level	200
0.0 -0.001	120
0.001-0.005	60
0.005-0.010	50
0.010-0.020	40
0.020-0.040	30
0.040-0.060	20

Border Strip Length

Long border strips are easier to farm than short strips because fewer turns by farm equipment are required. Some of the factors that can determine the maximum length of run in specific fields are flow hydraulics, field boundaries and barriers such as stream channels and drainage ditches, and changes in soil and in land slope. Border strips should not be laid out across two or more soil types that have different intake characteristics or different available water holding capacities, or both. Also, border strips should not extend across slopes that differ greatly from each other in steepness and length.

Occasionally, slope, soil, and hydraulic conditions are such that an extremely long run seems feasible. However, the time required to patrol long runs and the difficulties in determining and making needed adjustments in stream size usually make these runs impractical. Length of run in excess of a quarter mile seldom is satisfactory.

Border Ridge Height

On noncohesive soils, border ridges with a settled height of more than 8 inches are difficult to construct and maintain without making them excessively wide. Greater heights are practical on some cohesive soils, particularly if farm equipment does not need to be operated across the ridges. If large border ridges are planned, however, special provisions must be made for planting and harvesting of crops, and controlling of weeds. Also, it generally is difficult to wet through border ridges that are more than 1 foot high. In addition, where salinity is a problem, salt can accumulate in the ridge crest. The higher the ridge, the more pronounced the salt accumulation is likely to be.

Border ridges must be constructed so that crown width is at least as great as ridge height. Side slopes should be no steeper than 2-1/2 horizontal to 1 vertical. On noncohesive soils the side slopes should be no steeper than 3 to 1. Border ridges at the edge of field benches should be a little wider and higher than those normally required on unbenched fields.

Design Considerations

Soil Intake Characteristics

Designs for the border method depend on knowing the intake characteristics of the soils to be irrigated. Although each kind of soil has its own intake characteristics, the differences between some soils are so minor that, for all practical purposes, several soils can be considered together. For design purposes, almost all soils can be placed in one of eight intake groups called intake families. Each family has been assigned a number such as 0.1, 0.3, 0.5, etc., that represents the approximate value of the basic intake rate for soils in these families. These families are described by equations that have the general form:

$$F = a\,T_o^b + c$$

Table 4-2 gives the values of the parameters a (intercept of accumulated intake at unit time), b (exponent of time), and c (constant) for each family.

Table 4-2.--Values of parameters a, b, and c for standard intake families

Intake family	a	b	c
0.1	0.0244	0.661	0.275
0.3	.0368	.721	.275
0.5	.0467	.756	.275
1.0	.0701	.785	.275
1.5	.0899	.799	.275
2.0	.1084	.808	.275
3.0	.1437	.816	.275
4.0	.1750	.823	.275

Figure 4-1 shows the accumulated intake curve for each intake family and the range of values associated with each curve.

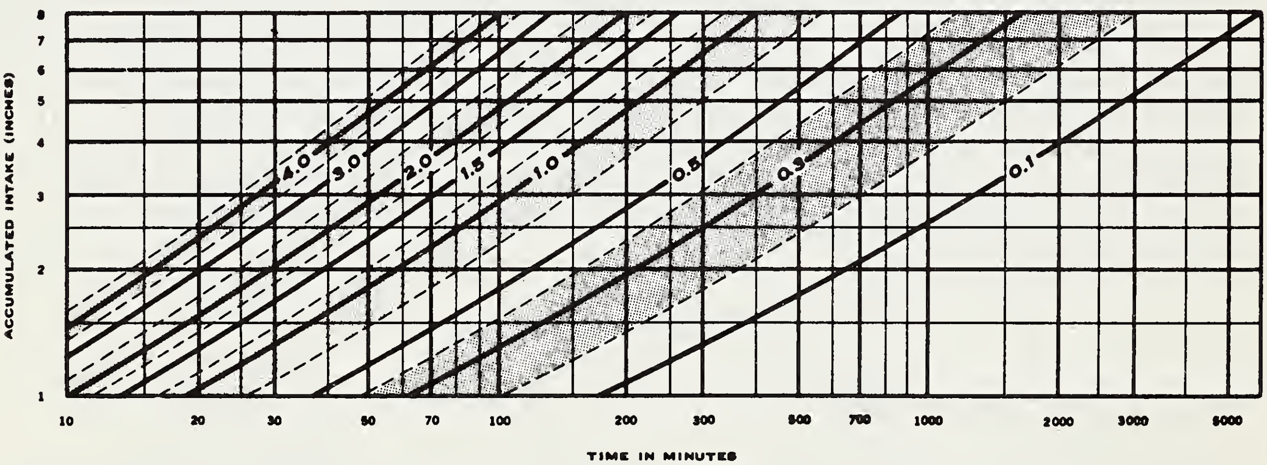


Figure 4-1.--Intake families for border irrigation design

Intake characteristics associated with border irrigation usually are measured by cylinder infiltrometers. They also are estimated by measuring the flow onto a border strip together with measuring the depth of water temporarily stored on the soil surface. For any given time period during which water is advancing down a border strip, the total volume of intake in the soil is equal to the volume of water run onto the border strip minus the volume temporarily stored on its surface. A series of intake measurements can be compared with those in figure 4-1 to determine the correct intake curve to use for design. (Soils that crack on drying or in which there are extreme differences between profile horizons may require special intake evaluations.)

Most irrigated soils can be associated with one of the intake families for design purposes. The design procedure is greatly simplified by this association, for standard charts and tables can then be prepared to show

the intake characteristics and design requirements by families. One example is the intake opportunity time required for various net depths of application for each intake family (see table 4-3).

Table 4-3.--Intake opportunity time for net depth of application for each family

Intake family	Net depth of application (F_n) in inches 1	1.5	2	2.5	3	4	5	6
	Minutes							
0.1	169	374	628	923	1,255	2,014	2,886	3,858
0.3	62.4	129	208	296	392	604	841	1,100
0.5	37.6	75.3	119	166	217	328	450	580
1.0	19.6	38.3	59.2	81.8	106	158	214	273
1.5	13.6	26.3	40.4	55.5	71.6	106	143	181
2.0	10.5	20.1	30.7	42.1	54.2	79.7	107	136
3.0	7.3	13.8	21.0	28.7	36.8	53.9	72.2	91.3
4.0	5.6	10.6	16.1	22.0	28.1	41.1	54.8	69.2

Roughness Coefficient

In the design procedures discussed later in this chapter, various forms of the Manning equation are used to describe the hydraulics of the three kinds of border irrigation. One of the important parameters in this equation is the roughness coefficient (n). This coefficient expresses the flow-retardance effects of different hydraulic boundary conditions. Some crops retard flow more than others. Height, density, shape, and stem stiffness of plants are some factors that affect retardance. Smooth, bare soil, such as found in noncultivated, oil-mulch-treated citrus groves, has the lowest hydraulic roughness of any condition normally associated with the border method of irrigation.

More studies are needed to define adequately the proper value of n for different (1) crops, (2) stages of crop growth, and (3) degrees of roughness of the soil surface. Until more information is available, based on field experience an n value of 0.04 can be used for smooth, bare soil surfaces and also for row crops irrigated by the level border method. An n value of 0.10 usually is accepted for drilled small grain crops if the drill rows run lengthwise of the border strip. An n value of 0.15 is suggested for alfalfa, mint, broadcast small grain, and similar crops. Dense sod crops and small grain crops that are drilled across the border strip can be expected to have an n value of about 0.25.

If design is limited by a maximum allowable flow depth, a conservatively high value of n should be used. On the other hand, if the design is limited by a minimum allowable stream size, a conservatively low n value should be chosen.

Kinds of Border Irrigation

Level Border

Water application is accomplished by ponding. The border strips have no slope in the direction of irrigation, and they are closed at the ends so the water is retained and absorbed into the soil. The irrigation stream must be large enough to cover the entire strip in a relatively small proportion of the time required for the soil to absorb the desired amount of water. The stream is turned off when the desired volume of water has been applied to the strip.

Adaptability

There are almost no crop restrictions with level border irrigation. It is widely used for close-growing crops such as alfalfa and other legumes, grasses, small grains, mint, and rice. It is used for row crops that can withstand some inundation, such as sugar beets, corn, grain sorghum, and cotton, and for other row crops if they are planted on beds so they will be above the water level. It also is well suited to the irrigation of tree crops, grapes, and berries.

This kind of irrigation is best suited to soils that have moderate to low intake rate (soils in the 2.0 intake family or less). It is the best way of applying water to soils that have an extremely low intake rate. It also can be used on soils that have a moderately high to high intake rate, but border strip areas may become undesirably small on the soils of higher intake rate.

Level border irrigation is best suited to smooth, gentle, uniform land slopes. Undulating or steep slopes can be prepared for this kind of irrigation, however, if the soils are deep enough to permit needed land leveling.

Advantages

Many different kinds of crops can be grown in sequence without making major changes in design, layout, or operating procedures. High application efficiency can be obtained easily. In fact, soils of low intake rate that are difficult to irrigate with graded or guide borders can be irrigated with level borders at an efficiency approaching 100 percent. No irrigation water is lost by runoff and little by deep percolation, and maximum use can be made of rainfall. Leaching operations are made easier; leaching can be done without changing either layout or method of operation. In addition, level border irrigation requires little labor; it is ideally suited to mechanization and can be adapted easily to automation or operated efficiently by inexperienced workers.

Limitations

Limitations are few; however, accurate land leveling is generally needed. Also, maintenance of a level surface is essential; such maintenance may require changing tillage operations or using special tools, or both. An adequate border ridge height may be difficult to maintain if the ridge

is constructed of sandy soil or of a fine-textured soil that cracks when dry. Excessive ponding and possible scalding can occur if the system is poorly managed. In some areas special provisions must be made for surface drainage. Drop structures, lined ditches, or pipelines may be required for adequate water control on steep slopes that require benching. Relatively large irrigating streams are needed; in some places two or more turnouts per border strip must be installed so that water is supplied at the needed rate without causing erosion.

Design Assumptions

The hydraulic principles of level border irrigation are comparatively simple. Water is applied to one end of the border strip at a rate that will provide coverage of the entire strip in a relatively short time. The water is then ponded until it infiltrates the soil. If a border strip could be covered instantaneously, all points on the strip would have the same intake opportunity time. Also, if the amount of water applied is limited to the net amount required, it should be possible to get an application efficiency of 100 percent. It is, of course, impossible to get instantaneous coverage of the border strip area. Therefore, some parts of the strip have a longer intake opportunity time than other parts, and efficiency decreases as these time differences increase.

Studies of the distribution of intake under various rate-of-advance curves show that a border strip can be irrigated satisfactorily if the following conditions are met:

1. The volume of water delivered to the border strip is adequate to cover the area of the border strip to an average depth that is equal to the gross irrigation application.
2. The intake opportunity time at the last point covered in the border strip is equal to the time required for the net irrigation to enter the soil.
3. The longest intake opportunity time at any point on the border strip is such that there is no detrimental deep percolation.
4. The depth of flow is no greater than can be contained by the border ridges.

The first condition refers to the gross application; the second condition depends on the net application. The difference between the gross and the net applications is equal to the deep percolation in the parts of the border strip having opportunity for intake in excess of the net irrigation.

Design Equations

Equations representing the flow of water on level borders are most useful if they pertain to a border strip 1 foot wide. On a unit-width border strip, the volume of water run onto the strip is equal to 60 $Q_u T_a$ cubic feet. If the volume is given in inches of average depth over the area, volume is written as 720 $Q_u T_a$ square feet-inches. The volume run onto the strip is equal to the volume of intake ($F_a L_t$) plus the volume of water in temporary surface storage (12 $d_a L_t$). From this

relationship a rate-of-advance equation can be developed.

$$720\ Q_u T_t = F_a L_t + 12\ d_a L_t \qquad \text{(Eq. 4-1)}$$

or

$$L_t = \frac{720\ Q_u T_t}{F_a + 12\ d_a} \qquad \text{(Eq. 4-2)}$$

Equation 4-2 is valid when the time of application (T_a) equals or exceeds the advance time (T_t). If the water is turned off before the advancing front has reached the end of the border strip, the actual rate of advance may be slightly slower than indicated.

The average depth of intake (F_a) can be developed most easily for a condition of uniform rate of advance. Likewise, the average depth of flow (d_a), or the average depth of surface storage, can be calculated most readily for a condition of flow over an impervious surface. Since the rate of advance is curvilinear rather than linear, however, the average depth of intake is underestimated. On the other hand, the average depth of surface storage correspondingly is overestimated. The indicated surface storage depth is greater than the actual surface storage depth because part of the water infiltrates the soil during advance. Since the two terms are combined, the errors involved are compensating and, therefore, do not significantly affect the overall results.

The general equation for accumulated intake of water into a soil can be written:

$$F = aT_o^b + c \qquad \text{(Eq. 4-3)}$$

Therefore, when advance is assumed to vary linearly with time, the average depth of water that infiltrates the soil in the time (T_t) required for the advancing front to reach a point L_t feet from the head of the border strip can be obtained by integrating equation 4-3 between the limits of T_t and zero and then dividing by T_t. Thus,

$$F_a = \frac{a}{1 + b}\ T_t^{\ b} + c \qquad \text{(Eq. 4-4)}$$

The maximum and average depth of water on an impervious level border strip at any time during the advance period can be computed on a quasi-rational basis using the Manning equation:

$$Q = A\ \frac{1.486}{n}\ r^{2/3}\ s_1^{\ 1/2} \qquad \text{(Eq. 4-5)}$$

In level border flow, considering a unit-width strip, $A = d_1$ and $r = d_1$, the hydraulic slope (s_1) equals d_1/Lt. Therefore,

$$Q_u = (d_1) \frac{1.486}{n} d_1^{\,2/3} \left(\frac{d_1}{L_t}\right)^{1/2} = \frac{1.486}{n\ L_t^{\,1/2}} (d_1)^{13/6} \qquad \text{(Eq. 4-6)}$$

or

$$d_1 = \left(\frac{1}{1.486}\right)^{6/13} n^{6/13}\ Q_u^{\,6/13}\ L_t^{\,3/13} \qquad \text{(Eq. 4-7)}$$

However, the volume of water run onto the border strip is equal to the average depth of surface storage times the length of advance. Therefore,

$$L_t = \frac{60\ Q_u T_a}{d_a} \qquad \text{(Eq. 4-8)}$$

Combining equations 4-7 and 4-8

$$d_1 = \left(\frac{1}{1.486}\right)^{6/13} (60)^{3/13}\ n^{6/13}\ Q_u^{\,9/13}\ T_a^{\,3/13}\ d_a^{\,-3/13} \qquad \text{(Eq. 4-9)}$$

Empirical studies have shown that on an impervious level surface the average depth of flow of an advancing stream is approximately 80 percent of the maximum depth, or $d_a = 0.80\ d_1$. Substituting this value in equation 4-9:

$$(d_1)\ (d_1)^{3/13} = \left(\frac{1}{1.486}\right)^{6/13} \left(\frac{60}{0.80}\right)^{3/13} n^{6/13}\ Q_u^{\,9/13}\ T_a^{\,3/13} \qquad \text{(Eq. 4-10)}$$

or

$$d_1 = \left[\left(\frac{1}{1.486}\right)^{6/13} (75)^{3/13}\ n^{6/13}\ Q_u^{\,9/13}\ T_a^{\,3/13}\right]^{13/16}$$

$$= \left(\frac{1}{1.486}\right)^{3/8} (75)^{3/16}\ n^{3/8}\ Q_u^{\,9/16}\ T_a^{\,3/16}$$

$$= 1.94\ n^{0.3750}\ Q_u^{\,0.5625}\ T_a^{\,0.1875} \qquad \text{(Eq. 4-11)}$$

And the average depth is only 0.8 as great, or:

$$d_a = 1.55\ n^{0.3750}\ Q_u^{\,0.5625}\ T_a^{\,0.1875} \qquad \text{(Eq. 4-12)}$$

If T_t is considered to be equal to T_a and equations 4-4 and 4-12 are combined with equation 4-2, the length of advance (L_t) can be related to the time of advance (T_t) for a given soil having intake parameters (a), (b), and (c); a given stream size (Q_u); and a given roughness coefficient (n) as follows:

$$L_t = \frac{720\ Q_u\ T_t}{\left[\dfrac{aT_t^{\ b}}{1 + b} + c + 18.6n^{0.3750}\ Q_u^{0.5625}\ T_t^{0.1875}\right]} \qquad \text{(Eq. 4-13)}$$

On a level border the water theoretically disappears from the entire surface at the same instant of time. Therefore, the total intake opportunity time (T_o) at any point can be estimated by adding the time required for the net irrigation to enter the soil (T_n) and the time required to cover the total length of run (T_t-total) and subtracting the time of advance to the point (T_t-point).

Figure 4-2 shows the advance curve, the intake opportunity time at each 100-foot station, and the average intake opportunity time for a 3-inch net application on a 1.0 family soil.

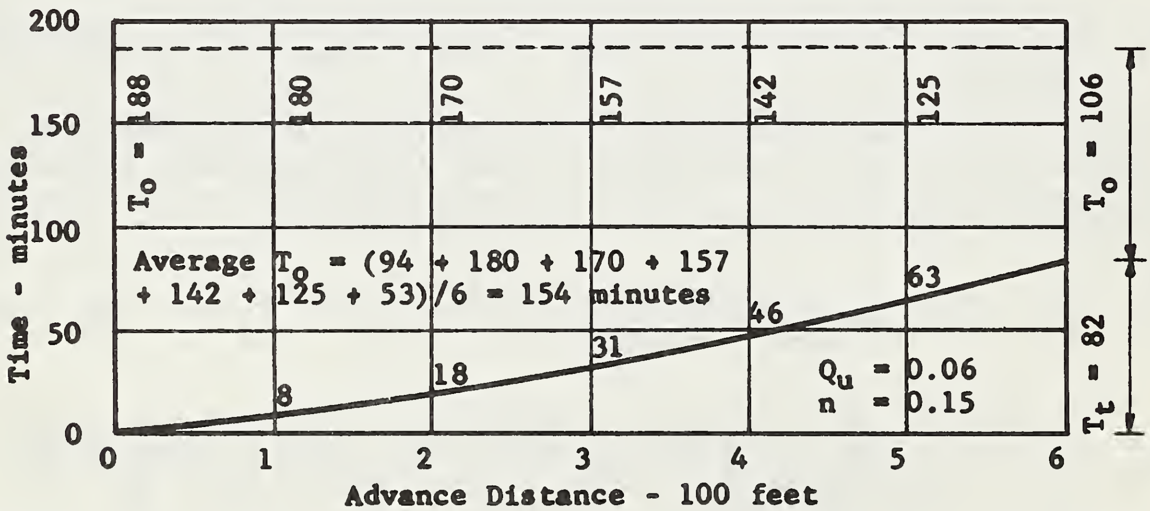


Figure 4-2.--Typical advance curve with computation of average intake opportunity time

The intake characteristics of a soil in the 1.0 family are represented by the equation $F = 0.0701\ T^{0.785} + 0.275$ (see table 4-2). If this equation is solved for the average intake opportunity time of 154 minutes, shown in figure 4-2, the average intake is 3.93 inches. This, then, is the gross average depth of water (F_g) that must be applied to get a 3-inch net depth of intake at the last point in the border strip that is covered by water.

The design efficiency (E) is 100 times the ratio of net depth of application (F_n) to gross depth of application (F_g):

$$E = \frac{100\ F_n}{F_g} \qquad \text{(Eq. 4-14)}$$

In figure 4-2, the design efficiency is 100 x 3.0/3.93 = 76 percent and the ratio of (T_t) to (T_n) is 82/106 = 0.774. Similar computations for various net depths of application and unit-width stream sizes have been made for each of the eight intake families. The computations show that design application efficiency is closely related to the ratio of T_t to T_n and can be estimated satisfactorily from the curve shown in figure 4-3.

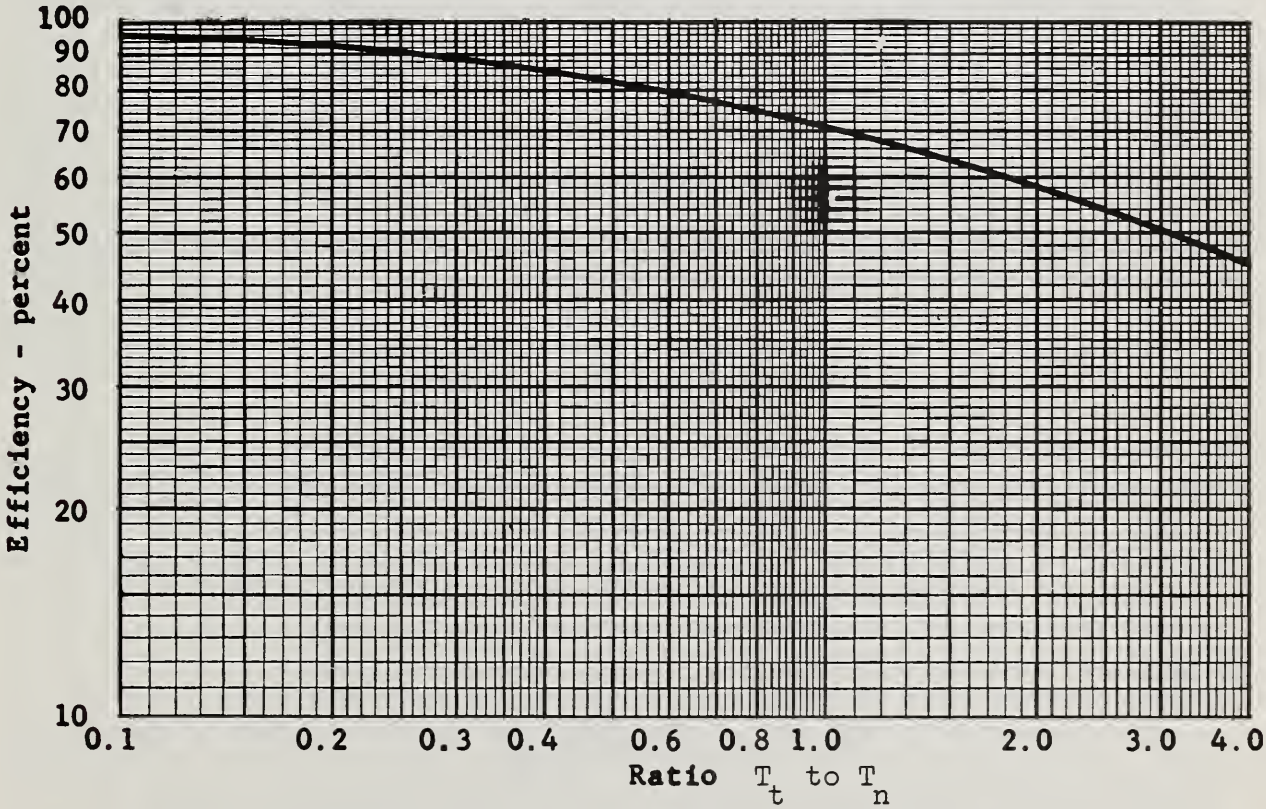


Figure 4-3.--Chart for estimating efficiency of level border irrigation

Table 4-4 has been developed from figure 4-3.

Table 4-4.--Ratio of T_t to T_n for various efficiency values

Efficiency	T_t to T_n
Percent	Ratio
95	0.16
90	.28
85	.40
80	.58
75	.80
70	1.08
65	1.45
60	1.90
55	2.45
50	3.20

If the application efficiency is known or is assumed, the gross application can be determined from the equation:

$$F_g = \frac{100\ F_n}{E} \qquad \text{(Eq. 4-15)}$$

The required time of application (T_a)--the time required to apply the gross application onto the border strip--can be computed as

$$T_a = \frac{F_g L}{720\ Q_u} \qquad \text{(Eq. 4-16)}$$

or as:

$$T_a = \frac{F_n\ L}{7.2\ Q_u\ E} \qquad \text{(Eq. 4-17)}$$

Note that the time of application may be greater or less than the time of coverage.

Design Limitations

In theory, maximum depth of flow and maximum deep percolation both occur at the point where water is introduced onto a level border strip. For any given set of site conditions, the depth of flow varies directly and the amount of deep percolation varies inversely with irrigation stream size per foot of border strip width (Q_u). Thus, if a limit is set on depth of flow, the only way to reduce deep percolation is to shorten the length of the border strip. If limits are set for both depth of flow and deep percolation, then the design limit for length is determined.

Maximum Depth of Flow.--Flow at the head end of level border strips must not exceed some practical depth related to the construction and maintenance of border ridges. Thus, an irrigation stream that can produce flow depth in excess of about 6 inches generally is inadvisable. Greater depth may be practical under special conditions, but depth of flow in excess of 8 or 10 inches seldom should be considered. Figure 4-4 can be used to estimate the depth of flow expected in level borders; it is a graphic solution of equation 4-11 with a roughness coefficient (n) of 0.15. Depth of flow associated with other values of n can be determined by multiplying the values represented in figure 4-4 by the appropriate conversion factors shown in the upper left corner of the chart.

Deep Percolation.--Since all the difference between net and gross irrigation applications is lost to deep percolation, it is desirable to limit this difference as much as possible. On many sites excess deep percolation causes acute drainage problems. To avoid this condition, the design efficiency usually should not be less than about 80 percent. Figure 4-3 shows that an 80 percent efficiency can be obtained if the time required to cover the border strip is not more than 60 percent of the time required for the net application to enter the soil. A design efficiency of less than 70 percent is considered only for soils having excellent internal drainage. On sites where irrigation water supplies are limited or costly, where subsurface drainage problems are acute, or where crops can be damaged by prolonged surface flooding, design efficiency in excess of 90 percent often is practical.

Construction Requirements

Land Leveling.--Although level borders are described and designed as flat-bottomed basins, there are reasons to justify variations in construction. First, it is difficult to construct and maintain a perfectly level land surface. Normal land leveling techniques do well to limit variations to 0.1 foot in the finished land surface. If leveling for a level border is staked as a level plane, the constructed land surface can contain low areas that are subject to excessive deep percolation or prolonged flooding that may damage crops. Also, the constructed land surface can contain reverse grades in the direction of irrigation. These reverse grades can retard the rate of advance and reduce application efficiency to considerably below design efficiency. To help avoid these conditions, fields can be staked for leveling with a slight grade in the direction of irrigation. However, the total fall in the length of the border strips cannot be more than about one-half the net depth of application used as a basis for design. No adjustment is made in the design to compensate for such slight grades.

Border furrows.--In addition to, or in lieu of, staking fields for a slight slope in the direction of irrigation, large furrows can be constructed and maintained on each side of the border ridges. The furrows help to speed rate of coverage of the border strip and to reduce depth of flow and deep percolation adjacent to the turnouts. These channels also facilitate removal of excess rainfall or irrigation water.

* Qu = border length in 100' x q

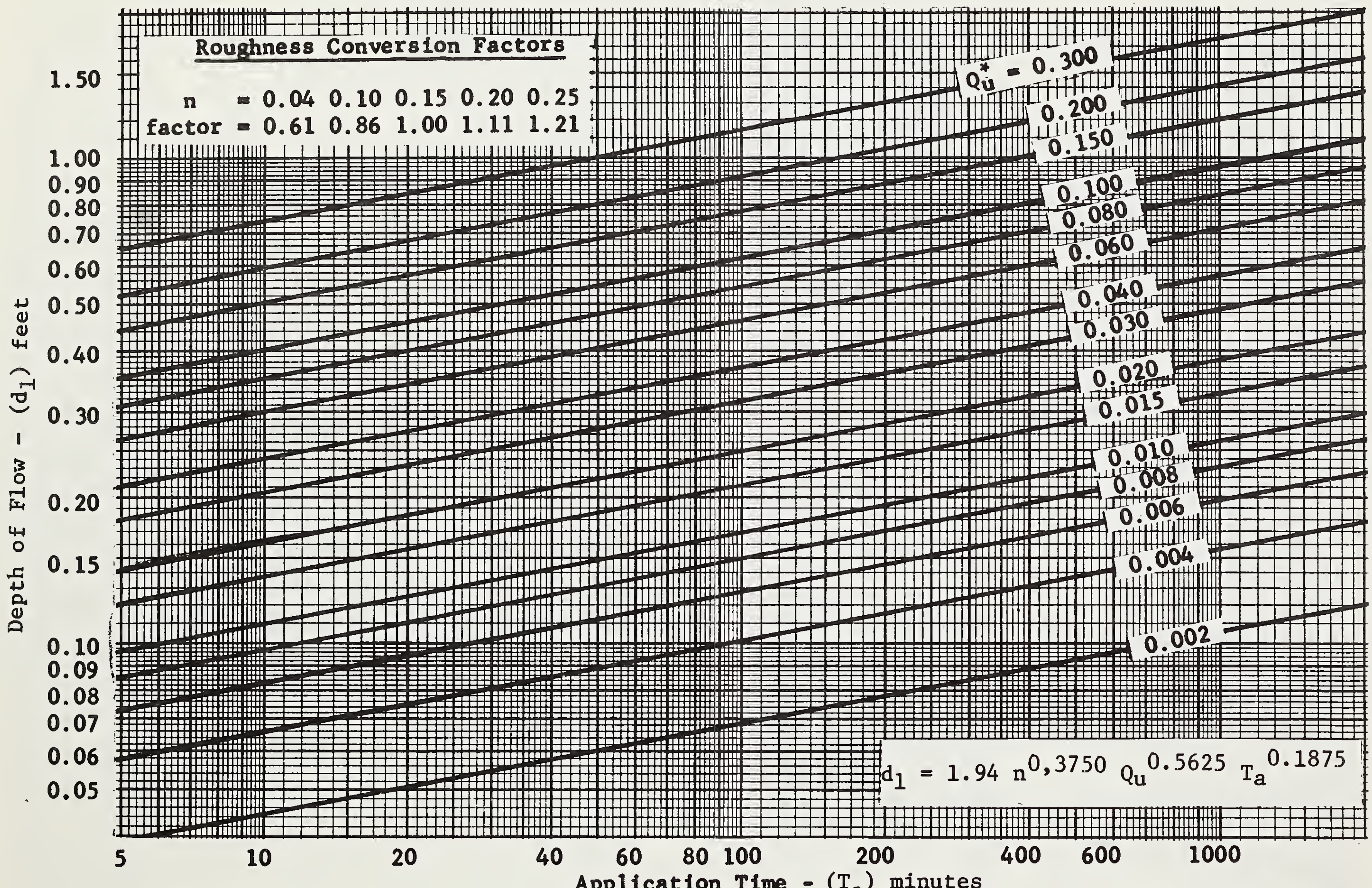


Figure 4-4.--Chart for estimating depth of flow in level borders with n of 0.15

Drainage facilities.--After an accidental overirrigation or periods of heavy rainfall, it may be necessary to drain excess water from level borders. The facilities needed are determined by how often such drainage may be needed. Surface drains usually are needed on soils of low intake rate or in areas subject to heavy summer rainstorms, or both. It is advisable to provide them for level borders on all soils in the 0.1 intake family and, in high rainfall areas, on soils in the 0.3 and 0.5 intake families. Under some circumstances they may be needed on soils of higher intake rate.

Turnouts.--Erosion on fields with level borders generally is not a problem. However, where velocity of the irrigation stream turned onto a border strip is in excess of about 3 feet per second, potholes or scour areas may develop adjacent to the turnouts. This possibility is not a limitation to design, but it does indicate a need for designing or selecting turnout structures that have a low velocity discharge rate or energy dissipation features.

Border Ridges.--Border ridges should be constructed so that crown width is at least as great as ridge height. The ridges can be built up so that they have a settled height at least equal to the greater of (1) the design gross depth of application (F_g) or (2) the design maximum depth of flow (d_1) plus 0.15 foot. If the time of application (T_a) exceeds the time of advance (T_t), the water depth on the border strip can exceed the maximum depth of flow (d_1) as computed according to equation 4-11.

Design Procedure

In preparing level border irrigation layouts, the designer must know the intake characteristics of the soil, must select a roughness coefficient value (n) that is appropriate for the crops to be irrigated, and must select the net depth of application (F_n) to be used as a basis for design. He then must determine one or more of the following:

1. Length of run that can be irrigated with a given stream size at a given efficiency.
2. Stream size needed to irrigate a given length of run at a given efficiency.
3. Maximum flow depth expected if using a given stream size and length of run that can be irrigated with that stream at a given efficiency.
4. Allowable stream size and related length of run at a given efficiency for a given maximum depth of flow.

Length of run (L) can be found for any given stream size (Q_u) and efficiency (E) by direct solution of equation 4-13. The time (T_n) required for the infiltration of the desired net application (F_n) and the constants a, b, and c can be determined from the soil intake curve. Then the allowable advance time (T_t) for any desired efficiency can be computed by multiplying T_n by the appropriate T_t to T_n ratio from figure 4-3 or table 4-4.

A similar solution for the stream size (Q_u) needed for a given length of run (L) and efficiency (E) is not possible. A trial-and-error procedure must be used.

The depth of flow expected with a given stream size (Q_u), efficiency (E), and related length of run (L) can be estimated by reference to figure 4-4. The application time (T_a) can be determined from equation 4-17.

The allowable stream size for a given maximum depth of flow (d_1) cannot be determined directly. A trial-and-error procedure must be used.

Design Charts

To simplify design procedure and eliminate trial and error solution of equations, a series of design charts have been prepared. Each chart is for a single intake family (I_F), a single roughness coefficient (n), and a single net depth of application (F_n). These charts for n values of 0.04, 0.15, and 0.25 are in appendices A, B, and C.

The design charts show relationships between the length of run, stream size, depth of flow, and time of application for any given or assumed efficiency. Figure 4-5 is a sample chart for an 0.15 n value, a 0.5 intake family, and a 3-inch net depth of application.

These charts are versatile. Almost any known or assumed value(s) can be the basis for design. If a field has border strips 750 feet long, for example, an irrigation stream of 0.071 cfs per foot of strip width is needed for 85 percent efficiency, 0.118 cfs for 90 percent efficiency, and only 0.043 cfs for 80 percent efficiency.

Based on the stream size required for 85 percent efficiency, the maximum depth of flow is 0.45 foot. If the design requirement is a maximum flow depth of 0.45 foot, the design can start at that point and the chart can be used to determine the maximum length of run and the required stream size for any desired efficiency. For the 85 percent efficiency shown in figure 4-5, the time of application is 52 minutes. With a stream of 0.043 cfs needed for an efficiency of 80 percent, the time of application is 91 minutes.

Graded Border

This is a balanced advance-and-recession kind of water application. The border strips have some slope in the direction of irrigation, and the ends usually are not closed. Each strip is irrigated by turning in a stream of water at the upper end. The stream size must be such that the desired volume of water is applied to the strip in a time equal to, or slightly less than, that needed for the soil to absorb the net amount required. When the desired volume of water has been delivered on to the strip, the stream is turned off. The water temporarily stored on the ground surface then moves on down the strip and completes the irrigation. Uniform and efficient application of water depends on the use of an irrigation stream of the proper size. Too large a stream results in

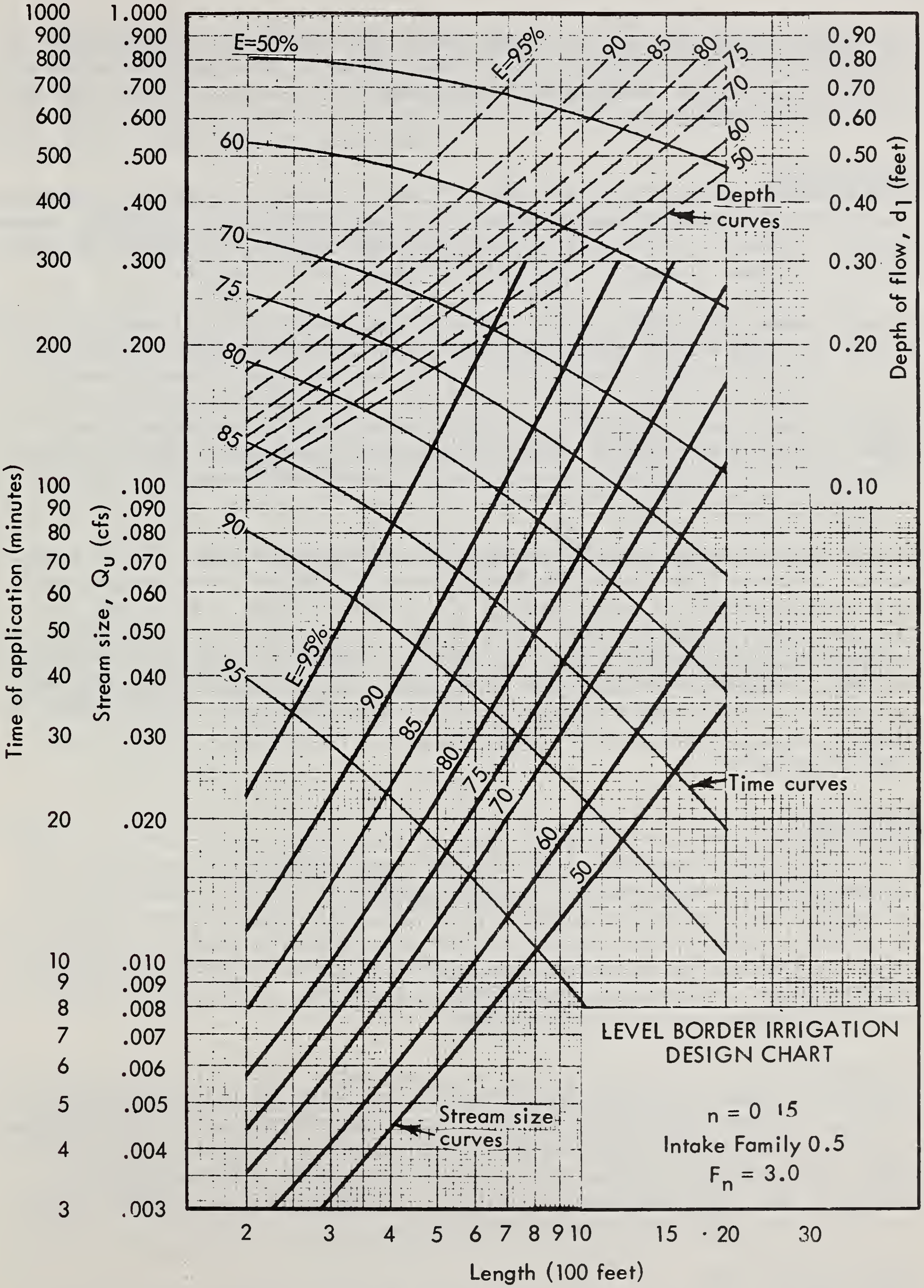


Figure 4-5.--Sample design chart for level border irrigation.

inadequate irrigation at the upper end of the strip or in excessive surface runoff at the lower end. If the stream is too small, the lower end of the strip is inadequately irrigated or the upper end has excessive deep percolation.

Adaptability

This kind of irrigation is suitable for all close-growing, noncultivated, sown or drilled crops, except rice and other crops grown in ponded water. Legumes, grasses, small grains, and mint are commonly irrigated by this method. It also is used to irrigate orchards and vineyards.

Graded border irrigation can be used on most soils. It is, however, best suited to soils with a moderately low to a moderately high intake rate (0.5 through 3.0 intake families). It is seldom used on coarse sandy soils of extremely high intake rate because of design limitations. Also, it is not well suited for use on soils of extremely low intake rate since, to provide adequate intake time without excessive surface runoff, the irrigating stream may be too small to cover the border strip completely.

Graded border irrigation is best suited to slopes of less than 0.5 percent. It can be used successfully on steeper slopes in areas where erosion from rainfall is not a hazard if the soil intake rate is not too low. For nonsodforming crops, this method is seldom used on slopes steeper than 2 percent. It can be used on slopes of 4 percent or steeper for the irrigation of sod crops if climatic conditions or supplementary irrigation methods can be depended on to establish good crop stands. On steeper slopes, border strips must be leveled carefully and all cross slope eliminated.

Advantages

Field application efficiency is good to excellent if the border strips are designed and installed properly and water management practices are followed. Labor requirements are low, and border strip dimensions can be designed for efficient operation of tilling, planting, and harvesting machinery. Within broad limits, border strips can be designed for irrigation grades that minimize land leveling costs. In areas where surface drainage is critical, graded borders provide an excellent means for removing excess surface water rapidly.

Limitations

The use of graded borders is limited by the need for (1) complete elimination of cross slope where soil intake characteristics or irrigation grades or both require small irrigating streams; (2) topography that is relatively smooth or soils that are deep enough to permit adequate leveling; and (3) considerable skill in irrigating, and skilled irrigators who often are not readily available.

Design Assumptions

The hydraulic characteristics of graded border irrigation are not completely known. Therefore, it is not possible to develop a completely

rational design procedure until these characteristics have been more adequately determined. If certain empirical hydraulic relationships are assumed valid, however, a rational or quasi-rational design in accord with relationships between soil intake, stream size, border area, and application depth can be developed.

On sites suitable for graded border irrigation, advance-and-recession curves will be reasonably well balanced and the area irrigated satisfactorily if these two conditions are met:

1. The volume of water delivered to the border strip is adequate to cover it to an average depth equal to the gross irrigation application.
2. The intake opportunity time at the head of the border is equal to the time necessary for the soil to absorb the net irrigation.

The first condition refers to the <u>gross</u> application; the second condition depends on the <u>net</u> application. The ratio between the net and the gross applications (field efficiency) must be estimated for conditions of the site under consideration. Also the proposed design procedure must be restricted to sites suitable for graded border irrigation. Empirical limits of site adaptation and guide information on design efficiency are given in table 4-12 on page 4-33.

<u>Design Equations</u>

The volume of water (V) needed to cover a border strip 1 foot wide to an average depth equal to the gross depth of application (F_g) and to satisfy the first condition can be stated as follows:

$$V = \frac{LF_g}{12} \qquad \text{(Eq. 4-18)}$$

where

$$F_g = \frac{100F_n}{E} \qquad \text{(Eq. 4-19)}$$

Therefore,

$$V = \frac{100LF_n}{12E} \qquad \text{(Eq. 4-20)}$$

Recession does not start immediately after the desired volume of water has been introduced to the head of the border strip. The time from the moment inflow is shut off until the impounded water has drained away from the head of the strip is known as the recession-lag time (T_L). For the intake opportunity time (T_o) to equal the time required for the soil to absorb the net irrigation (T_n) at the head of the strip, the time required to introduce the necessary volume of water is equal to (T_n) minus T_L. Therefore, to satisfy the second condition:

$$V = Q_u \, (T_n - T_L) \, 60 \qquad \text{(Eq. 4-21)}$$

Equating volumes for both conditions:

$$\frac{100LF_n}{12E} = 60\ Q_u\ (T_n - T_L) \qquad \text{(Eq. 4-22)}$$

So

$$L = 7.2Q_u\ (T_n - T_L)\ E/F_n \qquad \text{(Eq. 4-23a)}$$

or

$$Q_u = \frac{LF_n}{7.2\ (T_n - T_L)E} \qquad \text{(Eq. 4-23b)}$$

In equation 4-23b, the factors L and F_n usually are given. T_n, the time required for infiltration of the net depth of application (F_n), can be determined if the intake characteristics of the soil in the design area are known. However, approximating methods or estimates must be used to establish the values of T_L and E. The values of these factors may be estimated using figure 4-7 for lag time and table 4-12 for efficiency.

Relationship to Unit Stream Concept

The concept of a unit stream in border irrigation design was introduced about 1956. At that time, a unit stream was defined as the stream required for each 100 feet of border strip 1 foot wide (q). The basic assumption of this concept is that irrigation stream size is directly proportional to border strip area. Under this assumption--once the proper unit stream is determined for a given slope, soil, and depth of application--the actual irrigating stream for any set of border strip dimensions is merely the product of the unit stream and the number of unit areas in the strip.

The unit stream concept still seems valid. But the theoretical unit stream needed to satisfy intake requirements must be increased to compensate for lag in the start of recession. This increase is greatest on very gentle slopes and generally has no practical significance on slopes over 0.4 percent. If the unit stream (q) is considered as the flow that supplies an average depth of F_n inches to an area 1 foot wide and 100 feet long in time T_n, the unit stream can be computed as:

$$q = \frac{F_n}{7.2T_n} \qquad \text{(Eq. 4-24)}$$

The irrigation stream required per foot of border strip width then can be considered as:

$$Q_u = Kq \left[\frac{L}{100}\right] \left[\frac{100}{E}\right] \qquad \text{(Eq. 4-25)}$$

By comparing equations 4-23b and 4-25, it can be seen that the site factor (K) is the ratio of the required intake opportunity time to the required irrigation application time.

$$K = \frac{T_n}{T_n - T_L} \qquad \text{(Eq. 4-26)}$$

Recession-Lag Time

If, in equations 4-24, 25, and 26, the values of T_n and T_L are known or can be approximated, the relationship between L and Q_u can be determined for any assumed value of E. The intake time (T_n) corresponding to the required net depth of application (F_n) can be taken directly from the design intake curve for the site. The recession-lag time (T_L) can be considered as the time required to drain the water stored above the elevation of the upper end of the border strip at a rate equal to the just terminated rate of application.

As shown in figure 4-6, the recession volume (lined triangular area) can be computed:

$$\text{Recession volume} = (d_1/2)\ (d_1/s_1) = d_1^{\,2}/2s_1 \qquad \text{(Eq. 4-27)}$$

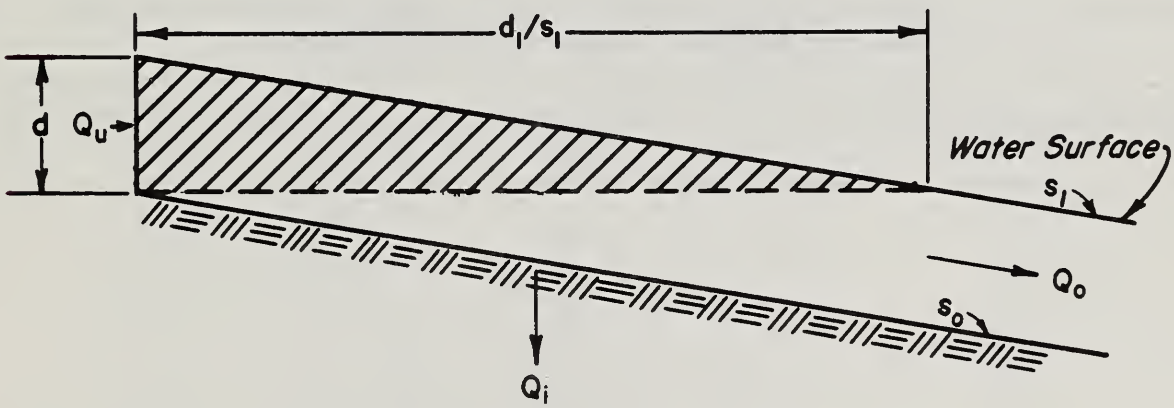


Figure 4-6.--Diagram of recession-lag time

If it is assumed that, within the recession-lag time, the depth of flow at the lower end of the reach (d_1/s_1) remains virtually unchanged, the flow (Q_o) moving downstream then remains unchanged. The intake rate (Q_i) also can be expected to remain nearly constant during the recession-lag period. Therefore, it also can be assumed that the total outflow draining the recession volume is Q_i plus Q_o, or Q_u. The recession-lag time can be computed as:

$$T_L = \frac{d_1^{\,2}/2s_1}{60\ Q_u} = \frac{d_1^{\,2}}{120\ Q_u s_1} \qquad \text{(Eq. 4-28)}$$

Flow at Normal Depth.--Assuming that water flows at normal depth in the border strip, i.e., $s_o = s_1$, the depth d_n is related to Q_u and slope as indicated by the Manning formula:

$$d_n = \frac{Q_u^{0.6}}{(1.486/n)^{0.6} \; s_o^{\;0.3}} \qquad \text{(Eq. 4-29)}$$

Also, if equation 4-29 is combined with equation 4-28, the recession-lag time can be related to Q_u, s_o, and n as follows:

$$T_L = \frac{Q_u^{0.2}}{120(1.486/n)^{1.2} \; s_o^{\;1.6}} \qquad \text{(Eq. 4-30)}$$

Figure 4-7 is a graphic solution of equations 4-29 and 4-30 when the Manning roughness coefficient (n) equals 0.15. Depth of flow and recession-lag time associated with other values of n can be determined by multiplying the values in figure 4-7 by the appropriate conversion factors in table 4-5.

Table 4-5.--Conversion factors for depth of flow and recession-lag time for various roughness coefficients

Roughness coefficient (n)	Flow depth (C_d)	Recession-lag time (C_t)
0.02	0.30	0.04
.04	.45	.21
.06	.58	.33
.08	.69	.47
.10	.79	.62
.15	1.00	1.00
.20	1.18	1.42
.25	1.35	1.85

On steep slopes flow approaches normal depth at the upper end of the border strip within a relatively short advance period. On more gentle slopes, however, flow may not reach normal depth within the required irrigating period. The recession-lag times and depths shown in figure 4-7, therefore, represent maximum values.

Flow at Less Than Normal Depth.--Estimates of flow depth and recession-lag time for low-gradient borders--where flow may not reach normal depth--are made by developing approximate water surface profiles for advancing streams. For developing these profiles, it is practical to assume that at any instant the friction slope in the Manning equation is equal to the irrigation slope, plus the depth of flow at the upper end

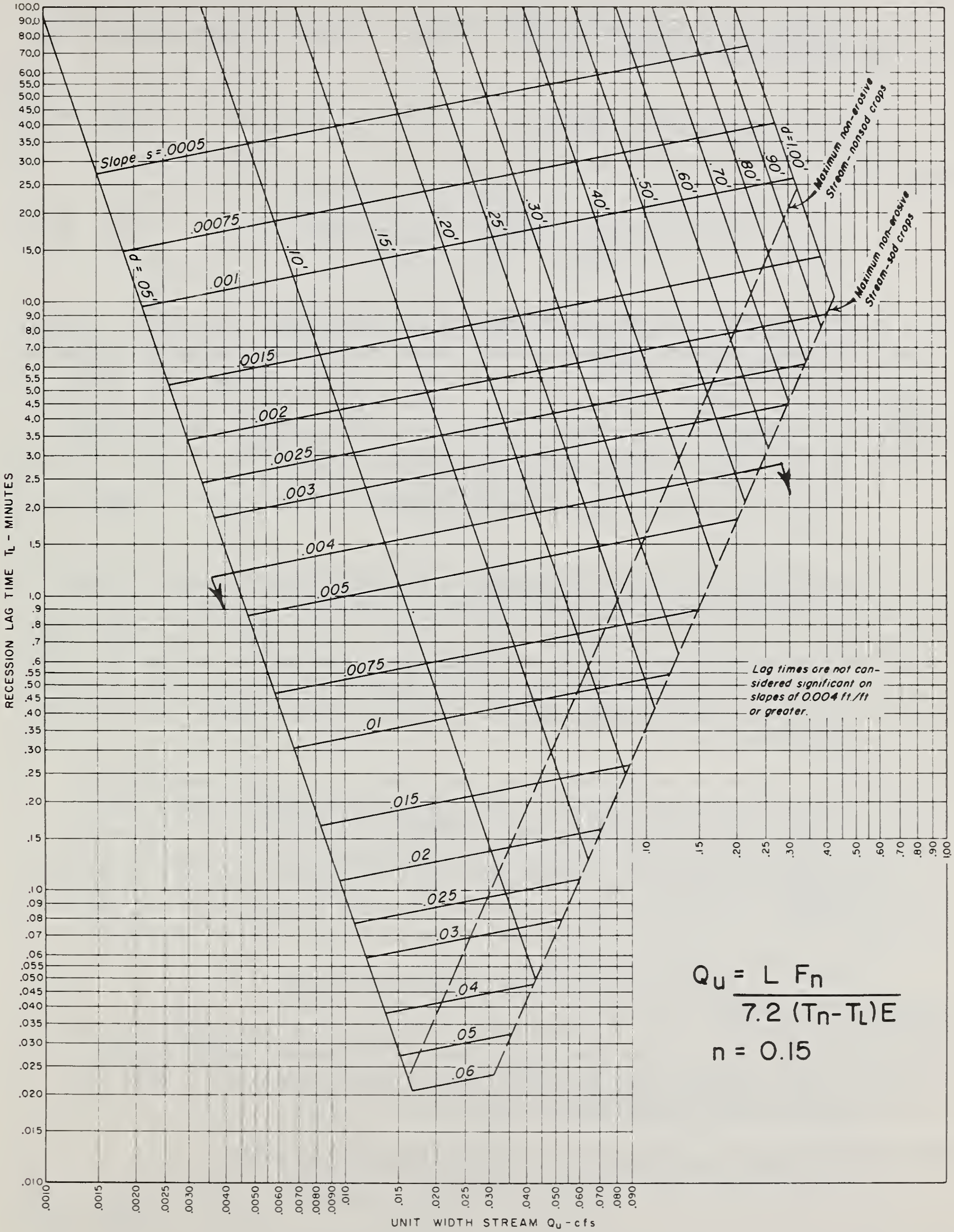


Figure 4-7.--Depth of flow and recession-lag time in graded border irrigation

of the border strip divided by the distance the stream has advanced up to that particular instant. Thus,

$$s_1 = s_o + d_1/L_t \qquad \text{(Eq. 4-31)}$$

and

$$d_1 = \frac{Q_u^{0.6}}{(1.486/n)^{0.6}(s_o + d_1/L_t)^{0.3}} \qquad \text{(Eq. 4-32)}$$

The water surface profiles for given values of stream size (Q_u), irrigation slope (s_o), and roughness coefficient (n) are developed by assuming a series of hydraulic slopes (s_1) and computing d_1, d_1/L_t, and L_t as illustrated in sample calculation 4-1. The profiles then can be related to time by summing the $(\Delta L_t)d_a$ values to obtain volume and dividing volume by the rate of application to obtain related time of application:

$$T_a = \frac{\Sigma[(\Delta L_t)d_a]}{60\ Q_u} \qquad \text{(Eq. 4-33)}$$

The recession-lag time corresponding to each assumed hydraulic slope value (s_1) can be computed using equation 4-28. The recession-lag time value then can be plotted against the intake opportunity time (T_o) and tabulated to provide a means of estimating T_L for any given border strip slope, unit-width stream, and required intake opportunity time. Table 4-6 is a design table developed for roughness coefficients (n) of 0.04, 0.15, and 0.25.

The depth of flow to be expected at the upper end of a low-gradient border strip can be estimated for any given unit-width stream and required intake opportunity time (see table 4-7). The normal depths of flow and recession-lag times shown in figure 4-7 can be used as a basis for designing border strips on slopes over 0.4 percent (0.004 feet per foot) without introducing any appreciable error (see tables 4-6 and 4-7). In fact, for the steeper slopes the recession-lag time is so short it has little practical significance.

<u>Design Limitations</u>

<u>Nonerosive Streams</u>.--The streams used in graded border irrigation must be nonerosive. To protect the upper end of the border strip against erosion, the irrigation stream per foot of strip width (Q_u) must not exceed the following empirical criteria:

For nonsodforming crops such as alfalfa and small grains:

$$Q_u \max = 0.0019\ s_o^{-0.75} \qquad \text{(Eq. 4-34)}$$

For well-established, dense sod crops:

$$Q_u \max = 0.0038\ s_o^{-0.75} \qquad \text{(Eq. 4-35)}$$

Sample calculation 4-1.--Depth of flow and recession-lag time as related to required intake opportunity time

[Assume $Q_u = 0.100$; $S_o = 0.002$; and $n = 0.150$]

S_1	$S_1^{0.3}$	d_1	$d_1/L_t = S_1 - S_o$	L_t	ΔL_t	d_a	$(\Delta L_t)\, d_a$	$\Sigma (\Delta L_t)\, d_a$	T_a	T_L	$T_o = T_a + T_L$
.1000	.501	.1266	.0980	1.292	1.292	.0633	0.082	0.082	0.01		
.0900	.485	.1308	.0880	1.486	0.194	.1287	0.025	0.107	0.02		
.0800	.469	.1353	.0780	1.735	0.249	.1331	0.033	0.140	0.02		
.0700	.450	.1410	.0680	2.074	0.339	.1382	0.047	0.187	0.03		
.0600	.430	.1476	.0580	2.545	0.471	.1443	0.068	0.255	0.04		
.0500	.406	.1563	.0480	3.256	0.711	.1520	0.108	0.363	0.06		
.0400	.380	.1670	.0380	4.395	1.139	.1617	0.184	0.547	0.09		
.0300	.350	.1813	.0280	6.475	2.080	.1742	0.362	0.909	0.15		
.0200	.309	.2053	.0180	11.406	4.931	.1933	0.953	1.862	0.31		
.0100	.251	.2528	.0080	31.600	20.194	.2291	4.626	6.488	1.08	0.53	1.61
.0090	.244	.2600	.0070	37.143	5.543	.2564	1.421	7.909	1.32	0.63	1.95
.0080	.235	.2700	.0060	45.000	7.857	.2650	2.082	9.991	1.67	0.76	2.43
.0070	.225	.2820	.0050	56.400	11.400	.2760	3.146	13.137	2.19	0.95	3.14
.0060	.215	.2951	.0040	73.775	17.375	.2886	5.014	18.151	3.03	1.21	4.24
.0050	.204	.3110	.0030	103.667	29.892	.3031	9.060	27.211	4.54	1.61	6.15
.0040	.191	.3322	.0020	166.100	62.433	.3216	20.078	47.289	7.88	2.30	10.18
.0030	.175	.3626	.0010	362.600	196.500	.3474	68.264	115.553	19.26	3.65	22.91
.0025	.166	.3822	.0005	764.400	401.800	.3724	149.630	265.183	44.20	4.87	49.07
.0024	.164	.3869	.0004	967.250	202.850	.3846	78.016	343.199	57.20	5.20	62.40
.0023	.162	.3917	.0003	1,305.667	338.417	.3893	131.746	474.945	79.16	5.56	84.72
.0022	.160	.3966	.0002	1,983.000	677.333	.3942	267.005	741.950	123.66	5.96	129.62
.0021	.157	.4041	.0001	4,041.000	2,058.000	.4004	824.023	1,565.973	261.00	6.48	267.48
.0020	.155	.4094	(Normal depth)							6.98	

Table 4-6.--Recession-lag time in low-gradient borders

Oppor. Time T_o	s_o = 0.0005				s_o = 0.001				s_o = 0.002				s_o = 0.004			
	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200
	Recession-Lag Time in Minutes for n = 0.04															
min.																
10	2.0	2.4	2.8	3.1	1.1	1.5	1.9	2.0			1.0	1.1				
30	3.4	4.5	5.6	6.0	1.4	2.1	3.0	3.3			1.2	1.4				
60	4.1	5.8	7.9	8.5	1.5	2.4	3.5	3.9			1.3	1.5				
100	4.5	6.6	9.4	10.3	1.6	2.5	3.8	4.2			1.4	1.6				
200	4.8	7.3	10.8	12.2	1.6	2.5	4.1	4.6			1.4	1.6	Note: Recession-lag times of less than one minute are omitted			
400	5.0	7.8	11.8	13.5	1.6	2.5	4.2	4.7			1.4	1.6				
600	5.0	7.9	12.2	14.0	1.6	2.5	4.2	4.8			1.4	1.6				
800	5.0	8.0	12.4	14.3	1.6	2.5	4.2	4.8			1.4	1.6				
1000	5.0	8.0	12.6	14.5	1.6	2.5	4.2	4.8			1.4	1.6				
2000	5.0	8.0	12.8	14.7	1.6	2.5	4.2	4.8			1.4	1.6				
	Recession-Lag Time in Minutes for n = 0.15															
min.																
10	3.2	3.3	3.4	3.4	2.4	2.7	3.0	3.1	1.5	1.9	2.2	2.4		1.0	1.4	1.5
30	7.3	8.2	8.9	9.2	4.6	5.7	6.8	7.1	2.1	3.0	4.1	4.5		1.3	1.9	2.1
60	11.3	13.6	15.5	16.3	5.9	8.1	10.3	10.9	2.4	3.6	5.2	5.7		1.4	2.1	2.3
100	14.5	18.4	22.1	23.3	6.6	9.6	13.0	14.0	2.6	3.9	5.7	6.4		1.4	2.2	2.4
200	18.4	25.3	33.0	35.0	7.4	10.9	16.1	17.7	2.7	4.2	6.3	7.2		1.5	2.3	2.6
400	21.2	30.7	43.3	47.5	8.0	11.8	18.1	20.4	2.8	4.3	6.7	7.6		1.5	2.3	2.6
600	22.4	33.4	48.5	53.5	8.2	12.3	19.0	21.7	2.8	4.4	6.8	7.8		1.5	2.3	2.6
800	23.0	35.0	51.3	57.3	8.2	12.5	19.6	22.3	2.8	4.4	6.9	7.9		1.5	2.3	2.7
1000	23.5	36.0	53.5	60.0	8.3	12.7	20.0	23.0	2.8	4.4	7.0	8.0		1.5	2.3	2.7
2000	24.7	38.0	58.0	66.0	8.4	13.0	20.7	23.7	2.8	4.4	7.0	8.0		1.5	2.3	2.7
	Recession-Lag Time in Minutes for n = 0.25															
min.																
10	3.2	3.4	3.5	3.5	2.7	3.0	3.1	3.3	2.0	2.4	2.8	2.8	1.1	1.5	1.8	2.0
30	8.3	9.2	9.7	9.9	6.1	7.1	8.0	8.3	3.4	4.5	5.7	6.0	1.4	2.1	3.0	3.3
60	14.4	16.2	17.6	18.2	8.8	11.0	13.3	14.1	4.0	5.7	7.8	8.5	1.5	2.3	3.5	3.9
100	20.7	23.4	26.5	27.4	10.6	14.2	18.0	19.3	4.4	6.4	9.2	10.2	1.6	2.5	3.7	4.2
200	29.4	35.7	43.0	45.0	12.4	17.9	24.1	26.8	4.7	7.2	10.7	12.0	1.7	2.6	4.0	4.6
400	37.0	48.5	63.0	67.0	13.8	20.5	29.3	33.4	4.9	7.6	11.7	13.2	1.7	2.7	4.1	4.7
600	40.8	54.5	74.5	81.0	14.5	21.6	32.0	36.3	5.0	7.8	12.2	13.7	1.7	2.7	4.1	4.8
800	42.0	58.0	82.0	90.0	14.8	22.0	33.7	38.0	5.0	7.9	12.4	14.0	1.7	2.7	4.1	4.8
1000	44.0	61.0	87.5	96.0	15.0	22.4	34.7	39.3	5.0	8.0	12.5	14.1	1.7	2.7	4.1	4.8
2000	45.5	68.0	99.0	110.0	15.6	23.0	36.7	41.0	5.0	8.0	12.8	14.5	1.7	2.7	4.1	4.8

Table 4-7.--Depth of flow in low-gradient borders

Oppor. Time T_o	s_o = 0.0005				s_o = 0.001				s_o = 0.002				s_o = 0.004			
	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200	Q_u 0.001	Q_u 0.010	Q_u 0.100	Q_u 0.200
					Depth of Flow in Feet when n = 0.04											
min.																
10	0.01	0.06	0.20	0.29	0.01	0.05	0.19	0.29	0.01	0.04	0.17	0.26	0.01	0.04	0.14	0.22
30	0.02	0.06	0.24	0.36	0.01	0.05	0.21	0.32	0.01	0.05	0.18	0.27	0.01	0.04	0.15	0.23
60	0.02	0.07	0.25	0.38	0.01	0.06	0.22	0.33	0.01	0.05	0.18	0.28	0.01	0.04	0.15	0.23
100	0.02	0.07	0.26	0.40	0.01	0.06	0.22	0.34	0.01	0.05	0.18	0.28	0.01	0.04	0.15	0.23
200	0.02	0.07	0.27	0.41	0.01	0.06	0.22	0.34	0.01	0.05	0.19	0.29	0.01	0.04	0.15	0.23
400	0.02	0.07	0.27	0.42	0.01	0.06	0.22	0.34	0.01	0.05	0.19	0.29	0.01	0.04	0.15	0.23
600	0.02	0.07	0.28	0.42	0.01	0.06	0.22	0.34	0.01	0.05	0.19	0.29	0.01	0.04	0.15	0.23
800	0.02	0.07	0.28	0.42	0.01	0.06	0.22	0.34	0.01	0.05	0.19	0.29	0.01	0.04	0.15	0.23
1000*	0.02	0.07	0.28	0.42	0.01	0.06	0.22	0.34	0.01	0.05	0.19	0.29	0.01	0.04	0.15	0.23
					Depth of Flow in Feet when n = 0.15											
min.																
10	0.02	0.09	0.36	0.53	0.02	0.09	0.34	0.52	0.02	0.09	0.33	0.49	0.02	0.08	0.30	0.45
30	0.03	0.12	0.43	0.64	0.03	0.11	0.41	0.60	0.02	0.10	0.37	0.56	0.02	0.08	0.32	0.48
60	0.03	0.13	0.47	0.71	0.03	0.12	0.44	0.66	0.02	0.10	0.38	0.58	0.02	0.08	0.32	0.49
100	0.04	0.14	0.51	0.76	0.03	0.12	0.46	0.68	0.03	0.10	0.39	0.60	0.02	0.08	0.33	0.50
200	0.04	0.14	0.55	0.81	0.03	0.12	0.47	0.72	0.03	0.10	0.40	0.61	0.02	0.08	0.33	0.50
400	0.04	0.15	0.58	0.86	0.03	0.12	0.48	0.73	0.03	0.10	0.40	0.62	0.02	0.08	0.33	0.50
600	0.04	0.15	0.59	0.88	0.03	0.12	0.49	0.74	0.03	0.10	0.41	0.62	0.02	0.08	0.33	0.50
800	0.04	0.15	0.60	0.89	0.03	0.12	0.49	0.74	0.03	0.10	0.41	0.62	0.02	0.08	0.33	0.50
1000*	0.04	0.16	0.60	0.90	0.03	0.13	0.50	0.75	0.03	0.10	0.41	0.62	0.02	0.08	0.33	0.50
					Depth of Flow in Feet when n = 0.25											
min.																
10	0.03	0.12	0.43	0.64	0.03	0.12	0.42	0.64	0.03	0.11	0.42	0.61	0.03	0.10	0.39	0.58
30	0.04	0.14	0.52	0.78	0.04	0.14	0.50	0.75	0.03	0.12	0.48	0.71	0.03	0.11	0.42	0.64
60	0.04	0.16	0.58	0.87	0.04	0.15	0.56	0.83	0.03	0.13	0.50	0.76	0.03	0.11	0.43	0.66
100	0.04	0.17	0.64	0.94	0.04	0.15	0.59	0.88	0.03	0.13	0.52	0.78	0.03	0.11	0.44	0.67
200	0.05	0.18	0.70	1.04	0.04	0.16	0.63	0.94	0.03	0.14	0.54	0.80	0.03	0.11	0.44	0.67
400	0.05	0.19	0.75	1.10	0.04	0.17	0.65	0.98	0.04	0.14	0.55	0.82	0.03	0.11	0.45	0.68
600	0.05	0.20	0.77	1.10	0.04	0.17	0.66	0.99	0.04	0.14	0.56	0.83	0.03	0.11	0.45	0.68
800	0.05	0.20	0.78	1.10	0.04	0.17	0.66	1.00	0.04	0.14	0.56	0.84	0.03	0.11	0.45	0.68
1000*	0.05	0.20	0.80	1.10	0.04	0.17	0.66	1.00	0.04	0.14	0.57	0.84	0.03	0.11	0.45	0.68

* Approximately normal flow depth at 1000 minutes

Table 4-8 gives the maximum nonerosive stream size for both sod and non-sodforming crops on various slopes. Figure 4-7 shows erosion limits for these crops.

Either turnouts that control flow onto the border strips must be designed to have a low-velocity discharge rate or energy dissipators must be used to prevent excessive scouring at the upper ends of the border strips. Turnout discharge velocity should be less than 3 feet per second.

Table 4-8.--Maximum value of Q_u for nonsod and sod crops by slope

Slope	Crops: Nonsod	Crops: Sod
Feet per feet	Cubic feet per second	
0.0005	0.567	1.113
.0010	.337	.674
.0020	.200	.400
.0030	.148	.296
.0040	.119	.238
.0050	.101	.202
.0075	.075	.149
.0100	.060	.120
.0150	.044	.089
.0200	.036	.072
.0250	.030	.060
.0300	.026	.053
.0400	.021	.042
.0500	.018	.036
.0600	.016	.031

Maximum Depth of Flow.--The flow at the head end of the border strip must not exceed some practical depth related to the construction and maintenance of border ridges. Therefore, an irrigation stream that is expected to produce a flow depth in excess of about 6 inches generally is inadvisable. Greater depth is practical on some soils, but depth of flow in excess of 8 or 10 inches should seldom be considered. The allowable stream (Q_u) per foot of border strip width for a given maximum depth of flow in low-gradient borders can be determined from table 4-9. This table was developed from computations of water surface profiles using n values of 0.04, 0.15, and 0.25. For border strips on slopes steeper than 0.4 percent, the allowable stream size can be determined from figure 4-7 and table 4-5.

Minimum Depth of Flow.-- The irrigating stream must be large enough so that the water spreads over the entire border strip. A larger stream is needed on rough strips than is required on adequately graded and smoothed

Table 4-9.--Allowable unit-width irrigation stream for given maximum depth of flow

		n = 0.04						n = 0.15						n = 0.25					
		Intake Opportunity Time - minutes						Intake Opportunity Time - minutes						Intake Opportunity Time - minutes					
Slope	Flow Depth	10	30	60	100	300	600	10	30	60	100	300	600	10	30	60	100	300	600
ft./ft.	feet	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
0.0005	0.1	.030	.022	.021	.020	.019	.018	.011	.008	.007	.006	.005	.005	.007	.006	.005	.004	.003	.003
	0.2	.100	.073	.067	.064	.060	.058	.036	.026	.022	.020	.017	.016	.025	.018	.015	.013	.011	.010
	0.3	.205	.147	.133	.128	.117	.113	.073	.054	.045	.040	.035	.032	.052	.038	.031	.027	.022	.020
	0.4	.340	.240	.217	.208	.190	.183	.120	.089	.075	.066	.056	.052	.086	.062	.051	.045	.036	.033
	0.5		.350	.316	.303	.275	.265	.178	.132	.110	.097	.083	.077	.128	.092	.076	.066	.053	.048
	0.6					.370	.357	.247	.183	.152	.133	.113	.105	.177	.127	.105	.091	.072	.065
	0.7							.320	.240	.200	.174	.146	.136	.235	.165	.137	.118	.094	.086
	0.8								.298	.250	.220	.185	.170	.298	.208	.173	.150	.118	.107
0.001	0.1	.032	.028	.027	.027	.027	.027	.011	.009	.008	.008	.007	.007	.008	.006	.005	.005	.004	.004
	0.2	.107	.091	.086	.086	.085	.084	.038	.029	.026	.024	.023	.022	.026	.020	.017	.016	.014	.013
	0.3	.215	.179	.170	.168	.166	.165	.079	.059	.052	.049	.045	.043	.053	.040	.034	.031	.028	.027
	0.4	.353	.292	.275	.272	.269	.267	.130	.096	.085	.079	.073	.070	.088	.067	.056	.052	.045	.043
	0.5			.397	.392	.388	.386	.195	.143	.125	.116	.106	.102	.130	.098	.083	.076	.066	.063
	0.6							.270	.198	.173	.159	.145	.139	.180	.135	.113	.103	.089	.086
	0.7							.345	.256	.224	.208	.189	.179	.237	.177	.148	.135	.117	.112
	0.8								.320	.280	.260	.236	.225	.300	.223	.187	.171	.146	.138
0.002	0.1	.041	.038	.036	.035	.035	.035	.012	.011	.010	.010	.010	.009	.008	.007	.006	.006	.006	.006
	0.2	.129	.120	.116	.112	.110	.109	.042	.035	.033	.032	.031	.030	.028	.023	.021	.020	.019	.018
	0.3	.255	.235	.228	.221	.218	.214	.085	.069	.065	.062	.061	.060	.057	.045	.042	.040	.037	.036
	0.4	.410	.380	.368	.360	.352	.345	.140	.113	.107	.102	.099	.097	.092	.075	.068	.065	.060	.058
	0.5							.220	.165	.155	.148	.145	.142	.138	.109	.100	.094	.088	.084
	0.6							.282	.225	.210	.200	.197	.193	.190	.150	.135	.128	.118	.113
	0.7							.370	.287	.271	.258	.255	.248	.250	.195	.176	.167	.154	.147
	0.8								.353	.340	.324	.310	.303	.315	.245	.222	.210	.198	.183
0.004	0.1	.054	.052	.052	.051	.051	.050	.015	.015	.014	.014	.014	.014	.009	.009	.009	.008	.008	.008
	0.2	.171	.163	.162	.160	.160	.160	.050	.046	.045	.045	.044	.043	.032	.029	.028	.027	.027	.026
	0.3	.338	.323	.320	.318	.316	.314	.100	.091	.088	.085	.085	.084	.064	.057	.055	.053	.052	.050
	0.4							.165	.148	.141	.138	.137	.135	.105	.092	.089	.086	.084	.082
	0.5							.240	.218	.207	.202	.200	.198	.155	.134	.130	.125	.122	.118
	0.6							.323	.293	.288	.280	.274	.265	.214	.182	.177	.169	.165	.161
	0.7								.380	.373	.363	.356	.347	.280	.236	.228	.220	.216	.210
	0.8													.357	.297	.285	.275	.267	.262

Note:
For $T_o > 600$ minutes, determine Q_u from Figure 4-7

strips. The irrigation stream per foot of strip width should be no less than is computed by equation 4-36:

$$Q_u = 0.000064 \ L \ s_o^{0.5}/n \qquad \text{(Eq. 4-36)}$$

Table 4-10 shows the minimum value of Q_u/L for various slopes and n values.

Table 4-10.--Minimum value of Q_u/L for various n values by slope

Slope	n = 0.04	n = 0.15	n = 0.25
Feet per foot		Cubic feet per second	
0.0005	0.00003578	0.00000954	0.00000572
.0010	.00005060	.00001349	.00000810
.0020	.00007155	.00001908	.00001145
.0030	.00008763	.00002337	.00001402
.0040	.00010120	.00002699	.00001619
.0050	.00011313	.00003017	.00001810
.0075	.00013855	.00003695	.00002217
.0100	.00016000	.00004267	.00002560
.0150	.00019600	.00005227	.00003136
.0200	.00022625	.00006033	.00003620
.0250	.00025295	.00006745	.00004047
.0300	.00027713	.00007390	.00004434
.0400	.00032000	.00008533	.00005120
.0500	.00035775	.00009540	.00005724
.0600	.00039185	.00010449	.00006270

Maximum Slope.--If equations 4-36 and 4-23b are combined, the maximum allowable slope for a given net depth of application can be determined for any given intake family and desired application efficiency.

$$0.000064 \ s^{0.5}/n = Fn/7.2 \ (T_n - T_L) \ E \qquad \text{(Eq. 4-37)}$$

or

$$s = \left[\frac{(n)}{0.0004608E} \ \frac{(F_n)}{T_n - T_L} \right]^2 \qquad \text{(Eq. 4-38)}$$

In using equation 4-38, the recession-lag time (T_L) can be ignored safely. The maximum slope found by the equation is based solely on the criteria for minimum depth of flow. In areas subject to erosion from rains of high intensity, that slope may be much too steep. Also, even

Table 4-11.--Maximum slopes for graded border irrigation as limited by minimum depth of flow requirements or by a minimum border length of 100 feet

Intake Family	Appl. Depth	n = 0.04 Efficiency - percent						n = 0.15 Efficiency - percent						n = 0.25 Efficiency - percent					
		50	55	60	65	70	75	50	55	60	65	70	75	50	55	60	65	70	75
	in.	Feet per foot						Feet per foot						Feet per foot					
0.3	1	.001*	.001*	.001*	.001*			.011*	.009*	.008*	.006*			.030*	.025*	.021*	.018*		
	2	#	#	#	#			.004*	.003*	.003*	.002*			.011*	.009*	.008*	.006*		
	3	#	#	#	#	#		.003*	.002*	.002*	.002*	.001*		.007*	.006*	.005*	.004*	.004*	
	4	#	#	#	#	#		.002*	.002*	.001*	.001*	.001*		.005*	.004*	.004*	.003*	.003*	
0.5	1	.002*	.002*	.001*	.001*			.030*	.025*	.021*	.018*			.083*	.069*	.058*	.049*		
	2	.001*	.001*	.001*	.001*			.012*	.010*	.008*	.007*			.033*	.027*	.023*	.020*		
	3	.001*	.001*	#	#	#		.008*	.007*	.006*	.005*	.004*		.023*	.019*	.016*	.013*	.011*	
	4	#	#	#	#	#		.006*	.005*	.004*	.004*	.003*		.018*	.014*	.012*	.010*	.009*	
	5	#	#	#	#	#		.005*	.004*	.004*	.003*	.003*		.015*	.012*	.010*	.009*	.007*	
1.0	1	.008*	.006*	.005*	.005*	.004*	.003*	.069	.078	.077*	.065*	.056*	.049*	.069	.078	.087	.097	.107	.118
	2	.003*	.003*	.002*	.002*	.002*	.002*	.048*	.040*	.034*	.029*	.025*	.022*	.119	.111*	.093*	.079*	.069*	.060*
	3	.002*	.002*	.002*	.001*	.001*	.001*	.034*	.028*	.024*	.020*	.017*	.015*	.094*	.078*	.065*	.056*	.048*	.042*
	4	.002*	.002*	.001*	.001*	.001*	.001*	.027*	.022*	.019*	.016*	.014*	.012*	.075*	.062*	.052*	.045*	.039*	.034*
	5	.002*	.001*	.001*	.001*	.001*	.001*	.023*	.019*	.016*	.014*	.012*	.010*	.064*	.053*	.045*	.038*	.033*	.029*
1.5	1	.016*	.013*	.011*	.010*	.008*	.007*	.042	.048	.054	.060	.066	.072	.042	.048	.054	.060	.066	.072
	2	.007*	.006*	.005*	.004*	.004*	.003*	.071	.081	.072*	.062*	.053*	.046*	.071	.081	.091	.101	.112	.123
	3	.005*	.004*	.004*	.003*	.003*	.002*	.074*	.062*	.052*	.044*	.038*	.033*	.089	.101	.114	.122*	.105*	.092*
	4	.004*	.004*	.003*	.003*	.002*	.002*	.060*	.050*	.042*	.036*	.031*	.027*	.103	.116	.116*	.099*	.086*	.075*
	5	.004*	.003*	.003*	.002*	.002*	.002*	.052*	.043*	.036*	.031*	.026*	.023*	.113	.119*	.100*	.085*	.073*	.064*
2.0	1	.027*	.023*	.019*	.016*	.014*	.012*	.030	.034	.038	.042	.047	.051	.030	.034	.038	.042	.047	.051
	2	.013*	.011*	.009*	.008*	.006*	.006*	.050	.056	.063	.070	.078	.080*	.050	.056	.063	.070	.078	.085
	3	.009*	.008*	.006*	.005*	.005*	.004*	.062	.070	.079	.077*	.066*	.058*	.062	.070	.079	.087	.096	.106
	4	.008*	.006*	.005*	.004*	.004*	.003*	.070	.080	.074*	.063*	.055*	.047*	.070	.080	.089	.100	.110	.12[illegible]
	5	.007*	.005*	.005*	.004*	.003*	.003*	.077	.077*	.064*	.055*	.047*	.041*	.077	.087	.098	.109	.120	.114*
3.0	1	.018	.021	.023	.026			.018	.021	.023	.026			.018	.021	.023	.026		
	2	.027*	.023*	.019*	.016*			.030	.034	.038	.042			.030	.034	.038	.042		
	3	.020*	.017*	.014*	.012*	.010*		.037	.042	.047	.052	.058		.037	.042	.047	.052	.058	
	4	.017*	.014*	.012*	.010*	.008*		.042	.047	.053	.059	.065		.042	.047	.053	.059	.065	
	5	.014*	.012*	.010*	.009*	.007*		.046	.052	.058	.065	.071		.046	.052	.058	.065	.071	
4.0	1	.013	.015	.016	.018			.013	.015	.016	.018			.013	.015	.016	.018		
	2	.021	.024	.027	.028*			.021	.024	.027	.030			.021	.024	.027	.030		
	3	.026	.028*	.024*	.020*	.018*		.026	.029	.033	.036	.040		.026	.029	.033	.036	.040	
	4	.029*	.024*	.020*	.017*	.015*		.029	.033	.037	.041	.045		.029	.033	.037	.041	.045	
	5	.025*	.021*	.017*	.015*	.013*		.032	.036	.040	.045	.050		.032	.036	.040	.045	.050	

Not adapted for graded borders

* Slope limited by depth requirements

in arid areas, graded border irrigation is not well suited to steeper slopes unless climatic conditions or supplementary irrigation methods can be depended on for establishing good crop stands. Even then, the maximum allowable nonerosive irrigation stream, as defined by equation 4-34, may be too small to permit a practical length of run.

Table 4-11 shows the maximum slope for graded border irrigation, as limited by minimum depth of flow requirements or by a minimum border length of 100 feet. Although table 4-11 indicates the theoretical possibility of using graded border irrigation on very steep slopes, it is much better suited to gentle slopes. On slopes over about 4 percent, erosion is an extreme hazard; it is doubtful whether the graded border method should ever be considered for slopes in excess of 6 percent.

Maximum Length of Run.--The theoretical maximum length of run for graded border irrigation is the length computed by equation 4-23a, using the maximum allowable stream per foot of border strip width (Q_{u1}). The maximum allowable stream is limited by the erosion hazard on steep slopes and by flow capacity of the border strips (allowable flow depth) on the flatter slopes. On some soils of low intake rate on gentle slopes, the theoretical maximum length of run can be several thousand feet. However, as discussed under "Layout Considerations," border lengths in excess of a quarter mile seldom should be designed.

Field Efficiency

Success in designing a graded border layout depends on the ability of the designer to make a reasonable estimate of the field efficiency that can be achieved on a particular site under a given set of management conditions. In most cases, the principal hazard is overestimating efficiency, which leads to designing border strips too long for adequate irrigation at the efficiency that can actually be attained. However, unless one of the design limitations is approached, selection of a design efficiency is not critical. Usually it is possible for the irrigator to adjust stream size enough for the layout designed to operate satisfactorily. In all irrigation methods, efficiency is affected more by the management practices of the irrigator than by any other factor. For a given management level, however, site conditions do have a significant effect on the efficiency achievable in border irrigation. Greater efficiency can be expected on gentle slopes than on steep slopes and on soils that have a moderate to moderately high intake rate than on soils that have either a low or extremely high intake rate.

On gently sloping well-leveled fields, if adequate facilities for the control and distribution of water are installed and good irrigation management practices are followed, a field efficiency of 60 to 75 percent usually is feasible. Table 4-12 shows the efficiencies commonly assumed for designing graded border irrigation.

Table 4-12.--Suggested design efficiency for graded border irrigation by slope and intake family

Irrigation slope s_o	Intake family 0.3				0.5					1.0					1.5					2.0					3.0				4.0			
Net depth of application (F_n) in inches	1	2	3	4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	4
Feet per foot	Percent																															
0.0005	65	65	70	70	65	65	70	70	70	75	75	80	80	80	75	75	80	80	80	75	75	80	80	80	65	70	70	70	65	70	70	70
.0010	60	60	65	65	65	65	70	70	70	70	70	75	75	75	75	75	80	80	80	75	75	80	80	80	65	70	70	70	65	70	70	70
.0020	60	60	55	50	65	65	70	70	70	65	65	70	70	70	70	70	75	75	75	70	70	75	75	75	65	70	70	70	65	70	70	70
.0030	55	55	50		60	60	65	65	65	65	65	70	70	70	65	65	70	70	70	65	65	70	70	70	65	70	70	70	65	70	70	70
.0040	55	50			60	60	65	60	55	60	60	65	65	65	65	65	70	70	70	65	65	70	70	70	65	70	70	70	60	65	65	65
.0050	50				60	60	60	55	50	60	60	65	65	65	65	65	70	70	70	65	65	70	70	70	65	70	70	70	60	65	65	65
.0075					55	55	50			60	60	65	65	65	60	60	65	65	65	65	65	70	70	70	65	70	70	70	60	65	65	65
.0100					55	55				60	60	65	65	65	60	60	65	65	65	60	60	65	65	65	60	65	65	65	60	65	65	65
.0150					55					55	55	60	60	60	60	60	65	65	65	60	60	65	65	65	60	65	65	65	60	65	65	65
.0200					50					55	55	60	55	50	60	60	65	65	65	60	60	65	65	65	60	65	65	65	60	65	65	65
.0250										55	55	55	50		60	60	65	65	65	60	60	65	65	65	60	65	65	65		60	60	60
.0300										55	55	50			55	55	60	60	60	55	55	60	60	60	55	60	60	60		60	60	60
.0400										50	50				55	55	60	60	55		55	60	60	60		60	60	60				
.0500															55	55	60	55	50		55	60	60	60								
.0600															50	50	55	50				55	55	55								

Design Procedure

One or more of the following determinations is needed for designing a layout for graded border irrigation:

1. Stream size needed to irrigate a given length of run.
2. Length of run that can be irrigated with a given stream size.
3. Maximum flow depth expected with a given stream size.
4. Allowable stream size for a given maximum depth of flow.

Before making these determinations, the designer must know or assume a number of design values. The following are items whose design values depend on soil, crop, and topography:

Item	Determinant
Intake family (I_F)	Soil
Irrigation slope (s_o)	Topography (can be changed)
Roughness coefficient (n)	Crop
Net depth of application (F_n)	Soil and crop
Field application efficiency (E)	Slope, soil, and crop
Nonerosive stream size (Q_u)	Slope and crop

The allowable stream size per foot of strip width for low-gradient borders at a given maximum depth of flow can be determined from table 4-9 and for graded borders having slopes greater than 0.4 percent from figure 4-7.

Table 4-7 shows the depth of flow expected in low-gradient borders and figure 4-7 shows the depth expected on slopes over 0.4 percent. Length of run (L) can be found for any given value of Q_u by direct solution of equation 4-23a. T_n, the time required for the infiltration of the desired net irrigation application (F_n), can be determined from the soil intake curve. The recession-lag time (T_L) can be determined from table 4-6 or, for borders steeper than 0.4 percent, from figure 4-7.

A direct solution for the stream size (Q_u) needed for a given length of run (L) is not possible, because the recession-lag time (T_L) on the right-hand side of equation 4-23b is a function of Q_u on the left-hand side. However, the general magnitude of recession-lag time expected for any given slope and intake opportunity time can be estimated from table 4-6 or figure 4-7, and Q_u determined by trial-and-error solution of equation 4-23b. (See sample calculation 4-2.) Usually there is no practical significance in attempting to determine the recession-lag time closer than the nearest whole minute.

Design Charts

To simplify design procedure, a series of design charts have been prepared. Each chart is for a single intake family (I_F), a single roughness coefficient (n), and a single net depth of application (F_n). These charts for n values of 0.04, 0.15, and 0.25 are in appendices D, E, and F.

Sample Calculation 4-2.--Trial-and-Error Solution of Equation 4-23b

Given:

Intake family (I_F)	0.5
Net depth of application (F_n)	4 inches
Irrigation slope (s_o)	0.001 feet per foot
Roughness coefficient (n)	0.15
Estimated field application efficiency (E)	65 percent
Length of run (L)	650 feet

Find:

Required unit-width stream size (Q_u)
Required time of application (T_a)

Solution:

T_n = 328 minutes (from intake curve)
$T_L \doteq$ 8 to 20 minutes (from table 4-6)

First trial:

Assume T_L = 14 minutes

$$Q_u = \frac{LF_n}{7.2(T_n - T_L)E} = \frac{(650)(4.0)}{(7.2)\ (328 - 14)(65)} = 0.018 \text{ cubic feet per second}$$

For $Q_u \doteq 0.018$ $\quad T_L \doteq 12$ minutes (from table 4-6)

Second trial:

Assume $T_L \doteq$ 12 minutes

$$Q_u = \frac{(650)(4.0)}{(7.2)(328 - 12)(65)} = 0.018 \text{ cubic feet per second} \qquad \text{OK}$$

$T_a \doteq 328 - 12 \doteq 316$ minutes

Check flow depth and stream size

Maximum depth of flow (d_1) = 0.15 feet (from table 4-7) OK

Minimum allowable $Q_u \doteq (0.00001349)\ (650) = 0.0088$
(from table 4-10) OK

Note: Unless the recession-lag time (T_L) is expected to be more than 25 percent of the required opportunity time (T_n), the first estimate of T_L provides for a sufficiently accurate estimate of the needed unit-width stream (Q_u).

The charts show the relationship between stream size and length of run for any given or assumed efficiency value by plotting the nondimensional ratio, length/efficiency as the abscissa and the stream size as the ordinate. Thus, if the designer wishes to find the length of run that can be irrigated with a given size of stream per foot of border strip width and a given efficiency, he determines the length-efficiency ratio for the given stream size and irrigation slope and multiplies this value by the given efficiency value.

The charts also show relationships between stream size and depth of flow and the required time of application. Depth, length-efficiency ratio, and time curves are shown for the full range of slopes for which graded borders are suitable. The maximum slope shown is the lesser of: (1) the steepest slope on which the minimum flow depth requirements can be met when irrigated at 50 percent efficiency; (2) the steepest slope that can be irrigated safely with a minimum length of run of 100 feet; or (3) 6 percent. The maximum nonerosive stream sizes are shown for sod-forming crops by the termination of the depth curves and by the tick mark (-) on the depth curves for nonsodforming crops. On all the charts the length-efficiency ratio is limited to a value of 30, which is equivalent to a length of 1,500 feet at 50 percent efficiency and proportionately longer lengths at higher efficiencies. Figure 4-8 is a sample chart of an 0.15 n value, a 1.0 intake family, and a 4-inch net depth of application.

These design charts are arranged so that for any selected efficiency almost any other known or assumed value can be used as a starting point; however, the charts should not be used to find efficiency values. For example, if a field having an irrigation grade of 0.4 percent (s_o = 0.004 feet per foot) has border strips 1,300 feet long, the needed stream size per foot of border strip width, the maximum flow depth, and the required time of application can be determined from the chart for any given or assumed efficiency. If it is assumed that the field can be irrigated at 65 percent efficiency, the length-efficiency ratio (1,300/65) is 20. For this value and a slope of 0.004 feet per foot, the required unit width stream is 0.072 cubic feet per second, the maximum depth of flow is 0.265 foot, and the time of application is 156 minutes.

In the above example, if the flow depth could not exceed 0.20 foot, the stream size would have to be reduced to 0.044 cubic feet per second, which would provide for a length-efficiency ratio of 12.1 or a border length of 790 feet. To find the maximum length of run for a slope of 2 percent and 55 percent efficiency, find the maximum nonerosive stream size for a nonsodforming crop opposite the dot on the proper depth curve. Follow this stream size (0.036 cfs) to the intersection with the length-efficiency ratio curve for a slope of 2 percent. The length-efficiency ratio is 10.1, and the maximum length of run is 555 feet (10.1 x 55).

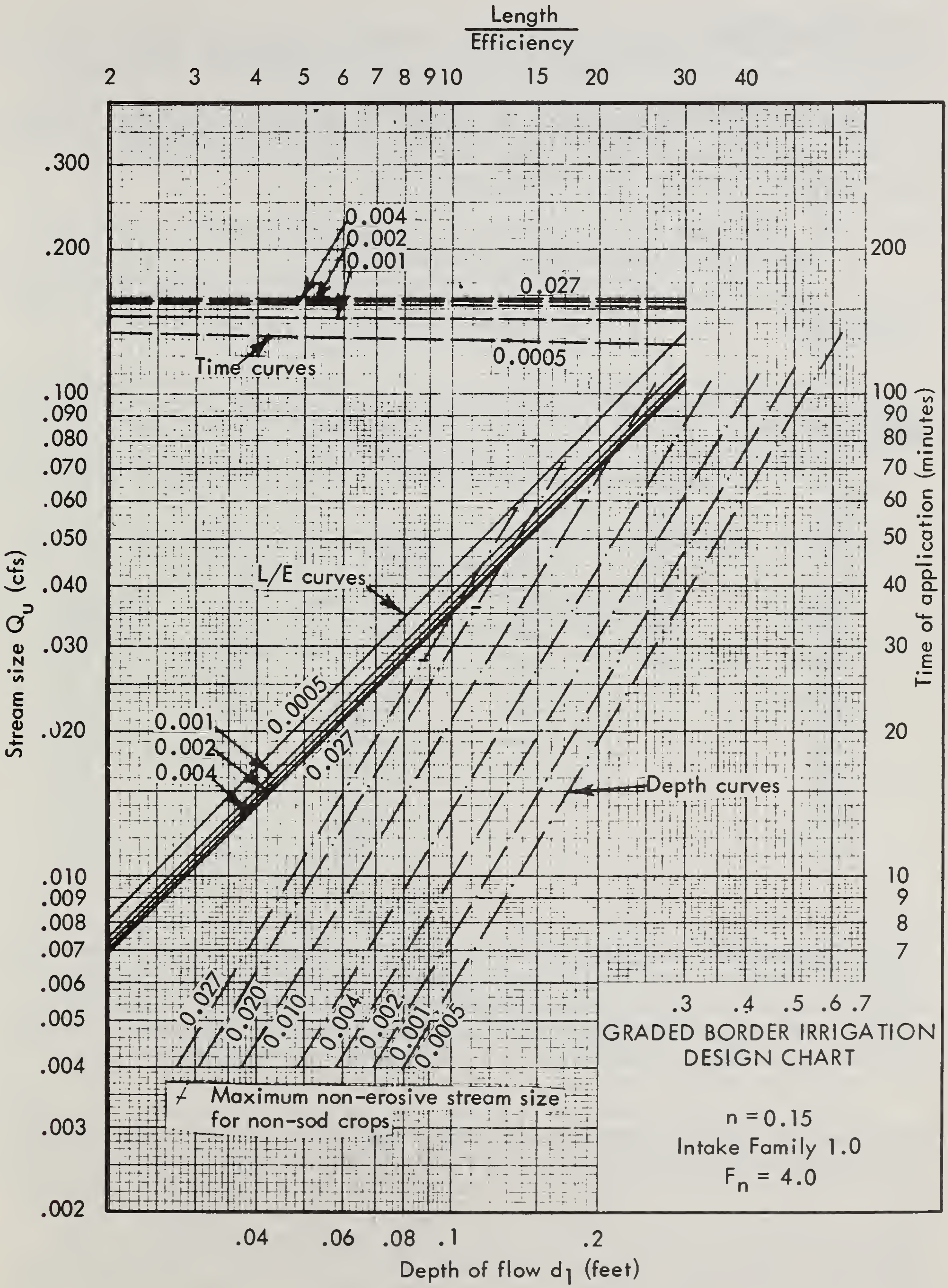


Figure 4-8.--Sample design chart for graded border irrigation

Use of End Blocks

Using end blocks to impound water that otherwise would be runoff or tailwater can result in a considerably higher application efficiency provided the impoundment affects a significant area. As a rule, if the net depth of application equals or exceeds 5 percent of the total fall in the length of the border strip, the use of end blocks should be considered in planning and design (see table 4-13).

Table 4-13.--Maximum border lengths for using end blocks by slope and net depth of application

Irrigation slope s_o	Net depth of application (F_n) in inches: 1	2	3	4	5
Feet per foot			Feet		
0.0005	3,333				
.0010	1,667				
.0020	833	1,667			
.0030	556	1,112	1,667		
.0040	417	833	1,250	1,667	
.0050	333	666	1,000	1,332	1,667
.0075	222	444	667	889	1,112
.0100	167	333	500	667	834
.0150	111	222	333	444	556
.0200		167	250	333	416
.0250		134	202	269	336
.0300		111	167	222	278
.0400			125	167	208
.0500			100	133	167
.0600				111	139

End blocks should not impound water to depths more than 1-1/2 times the depth of the net application, unless the area can be drained immediately after the required intake opportunity time has been met. Drainage is needed to avoid (1) excessive deep percolation, (2) crop damage from standing water, and (3) mosquito breeding. If surface drainage of rainfall is a problem, provision must be made for releasing this excess water.

Border ridges must be greater in height than the depth of water in the ponded area. All or part of that portion of the irrigation application that otherwise would be runoff can be held on the field, thus increasing the length of run that can be served by a given irrigation stream. Sites with soils of low intake rate, steep irrigation grade, or low roughness coefficient usually have more water available for impoundment than sites with soils of high intake rate, gentle irrigation grade, or high roughness coefficient.

The distance border strips can be lengthened by using end blocks is limited to the lesser of:

1. The length that can be covered by an impoundment whose maximum depth is equal to the desired net application depth

$$L_e = F_n/12\ s_o \quad \text{(Eq. 4-39)}$$

2. The length that can be adequately irrigated with the volume of water that would run off the open-end border strip

$$L_e = (1.00 - E/100)\ r_i\ r_n\ L \quad \text{(Eq. 4-40)}$$

In equations 4-39 and 4-40, L is the normal design length of run for open-end borders, L_e is the allowable length extension with end blocks, r_i and r_n are factors that express the effect of intake and roughness on runoff. Empirical values for these factors are given in table 4-14.

Table 4-14.--Intake and roughness factors for estimating potential runoff

Intake family	Factor (r_i)	Roughness coefficient (n)	Factor (r_n)
0.1	1.00	0.04	0.90
0.3	.90	.10	.80
0.5	.80	.15	.75
1.0	.70	.20	.70
1.5	.65	.25	.65
2.0	.60		
3.0	.50		
4.0	.40		

On sites where the irrigation grade is steep enough to make condition (1) limiting, the allowable extension can be increased to that computed under condition (2) by grading the field so the lower end of the run is level or nearly level. (See sample calculation 4-3 for the effect of end blocks on application efficiency and allowable length of run.) On fields where the length of run is fixed, using end blocks does not change the length but does permit using a reduced unit-width stream (Q_u'). The required stream size is that needed for a length of run (L') where this length plus the allowable extension (L_e') is equal to the fixed length L (see figure 4-9).

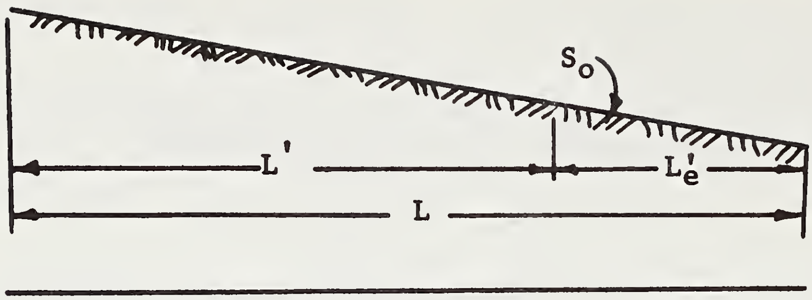


Figure 4-9.--Diagram of end block length extension

Length extensions are proportional to original lengths as shown by equation 4-40. Therefore:

$$L/L_e = L'/L_e' \qquad \text{(Eq. 4-41)}$$

or

$$L_e' = \frac{L' L_e}{L} \qquad \text{(Eq. 4-42)}$$

and

$$L' + \frac{L' \, L_e}{L} = L \qquad \text{(Eq. 4-43)}$$

Then

$$L' = \frac{L}{1 + \frac{L_e}{L}} \qquad \text{(Eq. 4-44)}$$

If L' is known, the required stream size (Q_u') can be computed by a trial-and-error procedure (see sample calculation 4-2). But since the reduction in stream size is likely to be enough to make a significant change in recession-lag time, the stream size is proportional to length and can be computed directly.

$$Q_u' = \frac{Q_u}{1 + \frac{L_e}{L}} \qquad \text{(Eq. 4-45)}$$

If equations 4-45 and 4-40 are combined, the required stream size can be related to estimated runoff as follows:

$$Q_u' = \frac{Q_u}{1 + (1.00 - E/100)\, r_i \, r_n} \qquad \text{(Eq. 4-46)}$$

Sample calculation 4-3.--Effect of end blocks on field application efficiency and length of run

Given:

Intake family (I_F)	1.0
Net depth of application (F_n)	3 inches
Irrigation slope (s_o)	0.001 feet per foot
Roughness coefficient (n)	0.15
Estimated field application efficiency (E)	75 percent
Allowable depth of flow at head of run (d_1)	0.3 feet

Find:

Allowable stream size (Q_u)
Required time of application (T_a)
Maximum length of run for open-end borders (L)
Allowable length extension with end blocks (L_e)
Efficiency with end blocks (E')

Solution:

T_n = 106 minutes (from intake curve)

Q_u = 0.049 cubic feet per second (from table 4-9)

T_L = 11 minutes (from table 4-6)

$T_a = (T_n - T_L) = 106 - 11 = \underline{95}$ minutes

$L = (7.2)(0.049)(106 - 11)(75)/3.0 = \underline{838}$ feet (Eq. 4-23a)

$L_e = 3.0/(12)(0.001) = 250$ feet (Eq. 4-39)

$L_e = (1.00 - 0.75)(0.70)(0.75)(838) = \underline{110}$ feet (Eq. 4-40)

$F_g = (720)(0.049)(106 - 11)/(838 + 110) = 3.54$ inches

$E = 3.0/3.54 = 0.85 = \underline{85}$ percent

As an example of this procedure, the stream size computed for the open-end borders 838-feet long, described in sample calculation 4-3, is 0.049 cubic feet per second. Using equation 4-46, the stream size needed for closed borders 838 feet long is:

$$Q_u' = \frac{0.049}{1 + (1.00 - 75/100)(0.70)(0.75)} = 0.0433 \text{ cubic feet per second}$$

The gross depth of application and resulting application efficiency are computed as follows:

$$F_g = 720\ Q_u(T_n - T_L)/L = (720)(0.0433)(106-11)/836 = 3.53 \text{ inches}$$

$$E = F_n/F_g = 3.0/3.53 = 0.85 = 85 \text{ percent}$$

Guide Border

In guide border irrigation, water is turned into the upper end of a sloping border strip and is allowed to run until a sufficient amount has infiltrated the soil. The stream size is not determined by the intake characteristics of the soil; it is determined by the hydraulic characteristics of the site. The stream must be large enough to provide adequate spreading over the strip, but it must not be so large as to cause erosion.

Adaptability

Guide border irrigation is used primarily to irrigate grasses, legumes, and grass-legume mixtures. It is also used to irrigate small grains customarily grown in rotation with the grasses and legumes. It is best suited to soils that have a moderate to very low intake rate. It is seldom used on soils in the 1.0 or higher intake families.

Guide borders are used on slopes as low as 0.1 percent where application depths of 1.5 inches or more are required on soils of very low intake rate (0.1 and 0.3 intake families). They are used on slopes as low as 0.3 or 0.4 percent for orchards with no cover crop on soils in the 1.0 intake family. For crops like alfalfa grown on soils in this intake family, guide borders may be suitable only on slopes steeper than 3.5 or 4.0 percent. Graded borders are used on the more gentle slopes.

Advantages

Since the stream size used is only large enough to insure complete coverage of the border strip, border ridges usually need to be no more than 2 or 3 inches high. There is little danger of their being overtopped and washed out. Costs of preparing land are low because the border strips are narrow. They are no wider than the length of the grading equipment blade, and the earth that spills around the ends of the blade forms the ridges. Each border strip can be leveled independently of the others. A considerable variation in downfield slope is acceptable as long as there are no grade reversals and all cross slope is eliminated.

Limitations

The major difficulty in using guide borders is irrigating new seedings adequately without causing erosion. On the steeper slopes it may be desirable to irrigate with sprinklers until a good crop stand has been established. On slopes up to 2 or 3 percent, shallow corrugations can be used to help keep the water spread over the border strip. Another limitation is the amount of surface runoff that must be handled. Since an irrigating stream large enough to insure spread over the border strip is larger than the stream needed to satisfy intake, a considerable part of the applied water runs off the lower end of the strip. Unless the runoff is collected for reuse, application efficiency is very low. This kind of irrigation also requires much labor, and the irrigator needs considerable skill to do a good job without causing excessive erosion.

Design Assumptions

Guide border irrigation is used where the irrigating stream needed to satisfy intake requirements and provide a balance between advance and recession for graded border irrigation is too small to spread over the border strip. This condition can be expected on steep slopes and on soils having a low intake rate. These strips can be irrigated satisfactorily by using the smallest stream that spreads adequately across the border strip and applying this stream for the time required for the soil at the upper end of the guide border strip to absorb the desired net depth of application.

Since the stream required for adequate spread is larger than needed to satisfy intake, much surface runoff can be anticipated and must be collected and reused or otherwise disposed of safely. The amount of runoff can be minimized by using the smallest stream that can spread out and completely cover the border strip.

Design Equations

Equation 4-36 describes the minimum stream needed per foot of border strip width to provide an adequate spread of water over strips that are reasonably well graded and smoothed.

$$Q_u = 0.000064\ L\ s_o^{0.5}/n \qquad \text{(Eq. 4-36)}$$

Table 4-10 shows minimum values of Q_u/L for various slopes and n values. Figures 4-10 and 4-11 show the relationship between stream size (Q_u) and length of run (L), as described by equation 4-36, for n values of 0.15 and 0.25 respectively.

Design Limitations

Minimum Slopes.--Guide border irrigation should be restricted to slopes that are too steep to be irrigated by graded borders at an acceptable efficiency level. Guide borders are designed only for slopes steeper than those shown in table 4-11 as limited by depth requirements. They cannot be used on slopes steeper than those shown as limited by the length of run requirement unless a border length of less than 100 feet is acceptable.

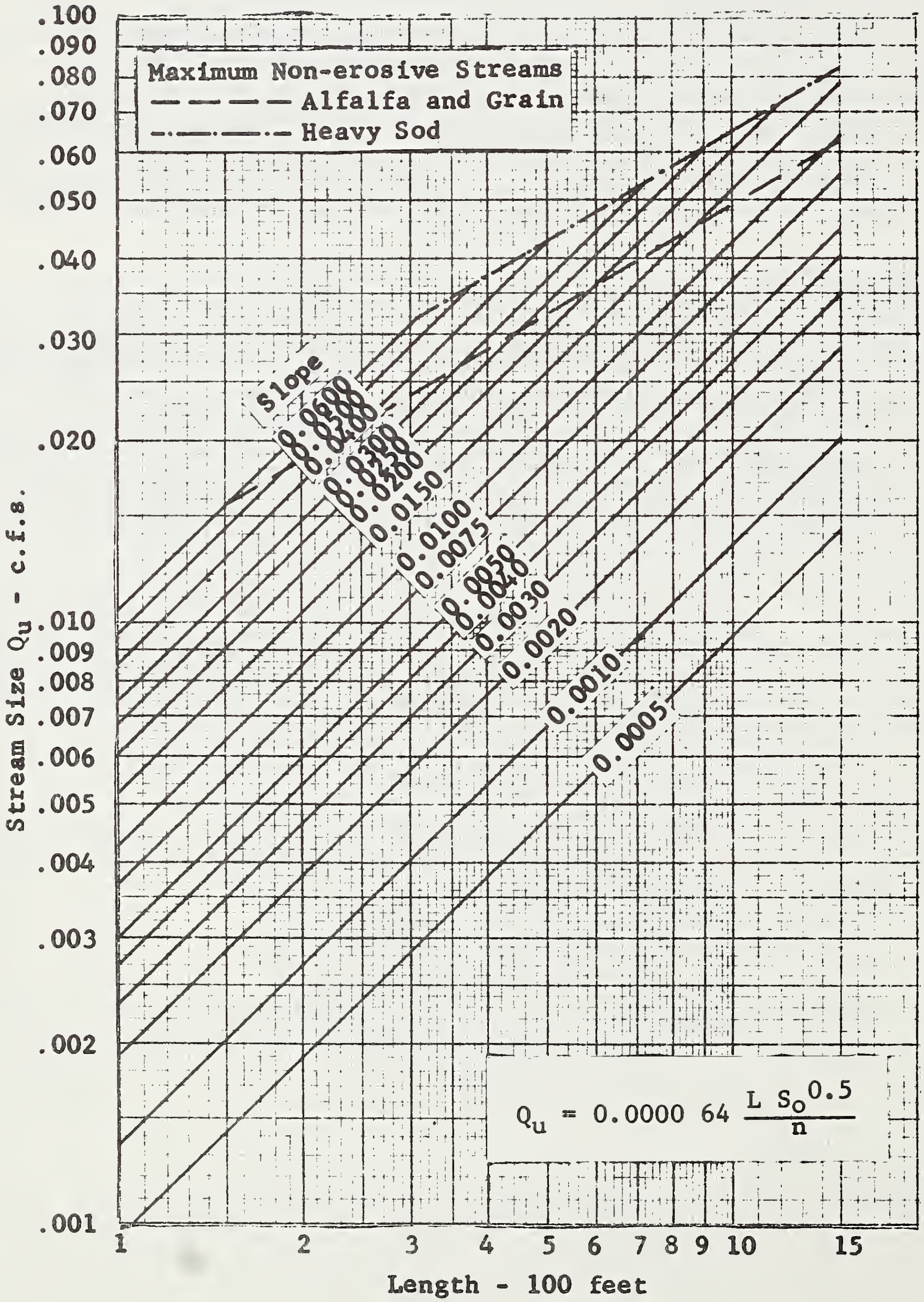


Figure 4-10.--Stream size and length of run relationship for guide border design when n = 0.15

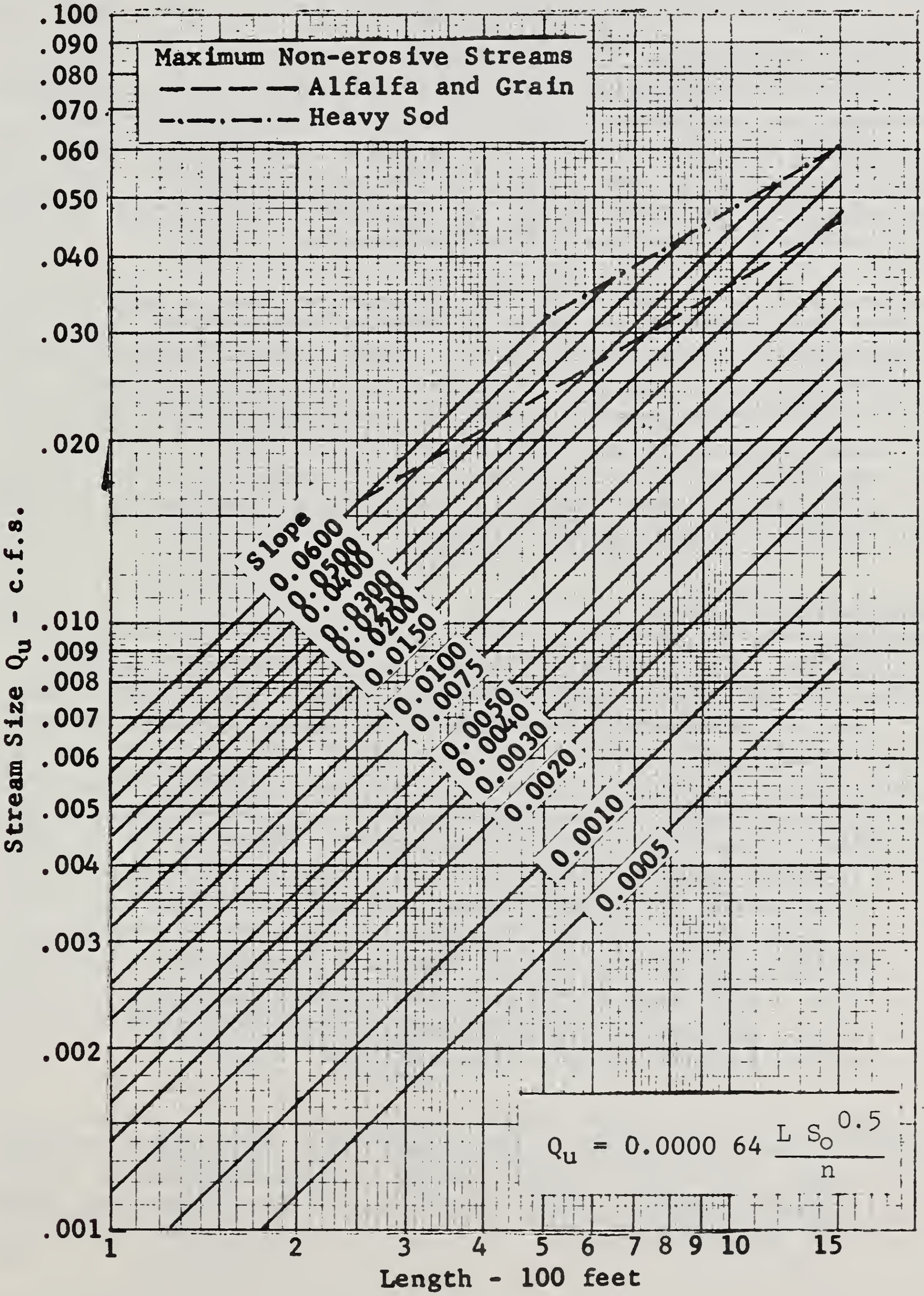


Figure 4-11.--Stream size and length of run relationship for guide border design when n = 0.25

Maximum Depth of Application.--The gross depth of application (F_g) that must be run onto a guide border strip is equal to the minimum required flow rate per foot of strip width multiplied by the required intake opportunity time and divided by the length of the border strip.

$$F_g = 720\ T_n\ Q_u/L \qquad \text{(Eq. 4-47)}$$

The gross depth of application must not be so great that the required volume exceeds the available supply. Also, the excess depth applied (F_g - F_n), which will be largely surface runoff, must not be more than can feasibly be collected and stored for reuse, conveyed to a field for immediate reuse, or returned safely to a natural stream or an irrigation conveyance system for eventual downstream reuse.

Tables 4-15, 4-16, 4-17, and 4-18 show the gross depth of application required for guide borders on soils in intake families 0.1, 0.3, 0.5 and 1.0. Developed from equation 4-47, these tables show the gross depth requirement for n values of 0.15 and 0.25. Soils in intake families 1.5 and higher generally are not irrigated in this way unless the roughness coefficient (n) is less than 0.15. This condition is found in some orchards and vineyards if cover crops are sparse or non-existent. With little or no vegetative protection, erosion is an extreme hazard on all but the most gentle slopes.

Construction Requirements

Land Leveling.--Guide borders have very shallow depths of flow. Therefore, the surface of the border strip must be made as smooth as is practicable with the usual land grading equipment. It is especially important that all side slope be removed. To insure a perfectly smooth transverse surface, guide border strips usually are made only as wide as the blade used in leveling. A leveling device is often attached to the blade to keep it exactly horizontal as the equipment travels up and down the border strip. Every precaution must be taken to reduce the possibility of leaving longitudinal low areas on which the flows can concentrate. It is easier to prepare border strips on well-leveled fields on which all cross slope has been removed. On relatively smooth natural slopes, however, guide border strips often are formed without prior leveling of the field. Each strip is graded independently. Attention is given to removing side slope. Longitudinal grades are smoothed, but usually no effort is made to make them uniform.

Border Ridges.--Since the flow depth in guide borders is shallow, border ridges usually need to be only a few inches high. Flow depth seldom exceeds 2 inches, and border ridges having a settled height of about 3 inches are adequate. Higher ridges may be needed for extra-long guide borders on very gentle slopes.

Table 4-15.--Required time of irrigation and gross depth of application for guide borders on 0.1 intake family soils

Irrigation slope	Minimum Q_u/L	$F_n = 1.0$ $T_a = 169$	$F_n = 1.5$ $T_a = 374$	$F_n = 2.0$ $T_a = 628$	$F_n = 2.5$ $T_a = 923$	$F_n = 3.0$ $T_a = 1255$
Feet per foot		Gross depth of application (Inches)				
		n = 0.15				
0.0005	0.00000954	1.16	2.57	4.31	6.34	8.62
.0010	.00001349	1.64	3.63	6.10	8.97	12.19
.0020	.00001908	2.32	5.14	8.63	12.68	
.0030	.00002337	2.84	6.29			
.0040	.00002699	3.28	7.27			
.0050	.00003017	3.67				
.0075	.00003695	4.50				
.0100	.00004267					
.0150	.00005227					
.0200	.00006033					
.0250	.00006745					
.0300	.00007390					
.0400	.00008533					
.0500	.00009540					
.0600	.00010449					
		n = 0.25				
.0005	.00000572	*	*	*	*	*
.0010	.00000810	*	*	*	5.38	7.32
.0020	.00001145	*	*	5.18	7.61	10.35
.0030	.00001402	*	3.78	6.34	9.32	12.67
.0040	.00001619	*	4.36	7.32	10.76	14.63
.0050	.00001810	2.20	4.87	8.18	12.03	
.0075	.00002217	2.70	5.97	10.02		
.0100	.00002560	3.12	6.89			
.0150	.00003136	3.82				
.0200	.00003620	4.40				
.0250	.00004047	4.92				
.0300	.00004434					
.0400	.00005120					
.0500	.00005724					
.0600	.00006270					

*Not adapted for guide borders. Values are omitted where $F_g > 5F_n$.

Table 4-16.--Required time of irrigation and gross depth of application for guide borders on 0.3 intake family soils

Irrigation slope	Minimum Q_u/L	$F_n = 1.0$ $T_a = 62$	$F_n = 1.5$ $T_a = 129$	$F_n = 2.0$ $T_a = 208$	$F_n = 3.0$ $T_a = 392$	$F_n = 4.0$ $T_a = 604$
Feet per foot		Gross depth of application (Inches)				
		n = 0.15				
0.0005	0.00000954	*	*	*	*	*
.0010	.00001349	*	*	*	*	*
.0020	.00001908	*	*	*	*	*
.0030	.00002337	*	*	*	*	10.16
.0040	.00002699	*	*	*	7.62	11.74
.0050	.00003017	*	*	4.52	8.52	13.12
.0075	.00003695	*	3.43	5.53	10.43	16.07
.0100	.00004267	*	3.96	6.39	12.04	18.56
.0150	.00005227	2.33	4.85	7.83	14.75	
.0200	.00006033	2.69	5.60	9.04		
.0250	.00006745	3.01	6.26	10.10		
.0300	.00007390	3.30	6.86			
.0400	.00008533	3.81				
.0500	.00009540	4.26				
.0600	.00010449	4.66				
		n = 0.25				
.0005	.00000572	*	*	*	*	*
.0010	.00000810	*	*	*	*	*
.0020	.00001145	*	*	*	*	*
.0030	.00001402	*	*	*	*	*
.0040	.00001619	*	*	*	*	*
.0050	.00001810	*	*	*	*	*
.0075	.00002217	*	*	*	6.26	9.64
.0100	.00002560	*	*	*	7.23	11.13
.0150	.00003136	*	*	4.70	8.85	13.64
.0200	.00003620	*	3.36	5.42	10.22	15.74
.0250	.00004047	*	3.76	6.06	11.42	17.60
.0300	.00004434	*	4.12	6.64	12.51	19.28
.0400	.00005120	2.29	4.76	7.67	14.45	
.0500	.00005724	2.56	5.32	8.57		
.0600	.00006270	2.80	5.82	9.39		

*Not adapted for guide borders. Values are omitted where $F_g > F_n$.

Table 4-17.--Required time of irrigation and gross depth of application for guide borders on 0.5 intake family soils

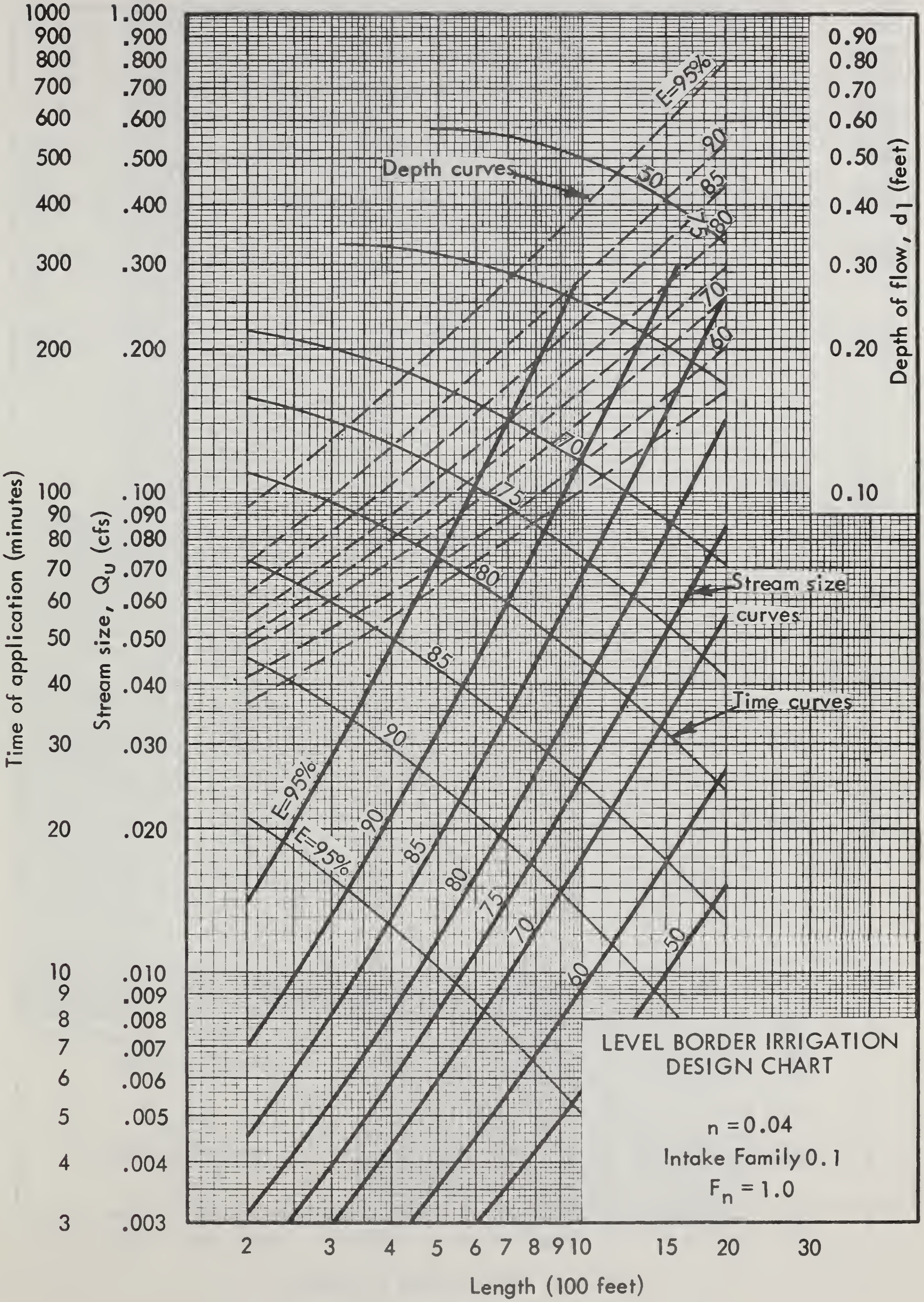
Irrigation slope	Minimum Q_u/L	$F_n = 1.0$ $T_a = 38$	$F_n = 2.0$ $T_a = 119$	$F_n = 3.0$ $T_a = 217$	$F_n = 4.0$ $T_a = 328$	$F_n = 5.0$ $T_a = 450$
Feet per foot		Gross depth of application (Inches) n = 0.15				
0.0005	0.00000954	*	*	*	*	*
.0010	.00001349	*	*	*	*	*
.0020	.00001908	*	*	*	*	*
.0030	.00002337	*	*	*	*	*
.0040	.00002699	*	*	*	*	*
.0050	.00003017	*	*	*	*	*
.0075	.00003695	*	*	*	8.73	11.97
.0100	.00004267	*	*	6.67	10.08	13.82
.0150	.00005227	*	4.48	8.17	12.34	16.94
.0200	.00006033	*	5.17	9.43	14.25	19.55
.0250	.00006745	*	5.78	10.53	15.93	21.85
.0300	.00007390	*	6.33	11.55	17.45	23.94
.0400	.00008533	2.33	7.31	13.33	20.15	
.0500	.00009540	2.61	8.17	14.91		
.0600	.00010449	2.86	8.95			
		n = 0.25				
.0005	.00000572	*	*	*	*	*
.0010	.00000810	*	*	*	*	*
.0020	.00001145	*	*	*	*	*
.0030	.00001402	*	*	*	*	*
.0040	.00001619	*	*	*	*	*
.0050	.00001810	*	*	*	*	*
.0075	.00002217	*	*	*	*	*
.0100	.00002560	*	*	*	*	*
.0150	.00003136	*	*	*	*	*
.0200	.00003620	*	*	*	8.55	11.73
.0250	.00004047	*	*	6.32	9.56	13.11
.0300	.00004434	*	*	6.93	10.47	14.37
.0400	.00005120	*	4.39	8.00	12.09	16.59
.0500	.00005724	*	4.90	8.94	13.52	18.55
.0600	.00006270	*	5.37	9.80	14.81	20.31

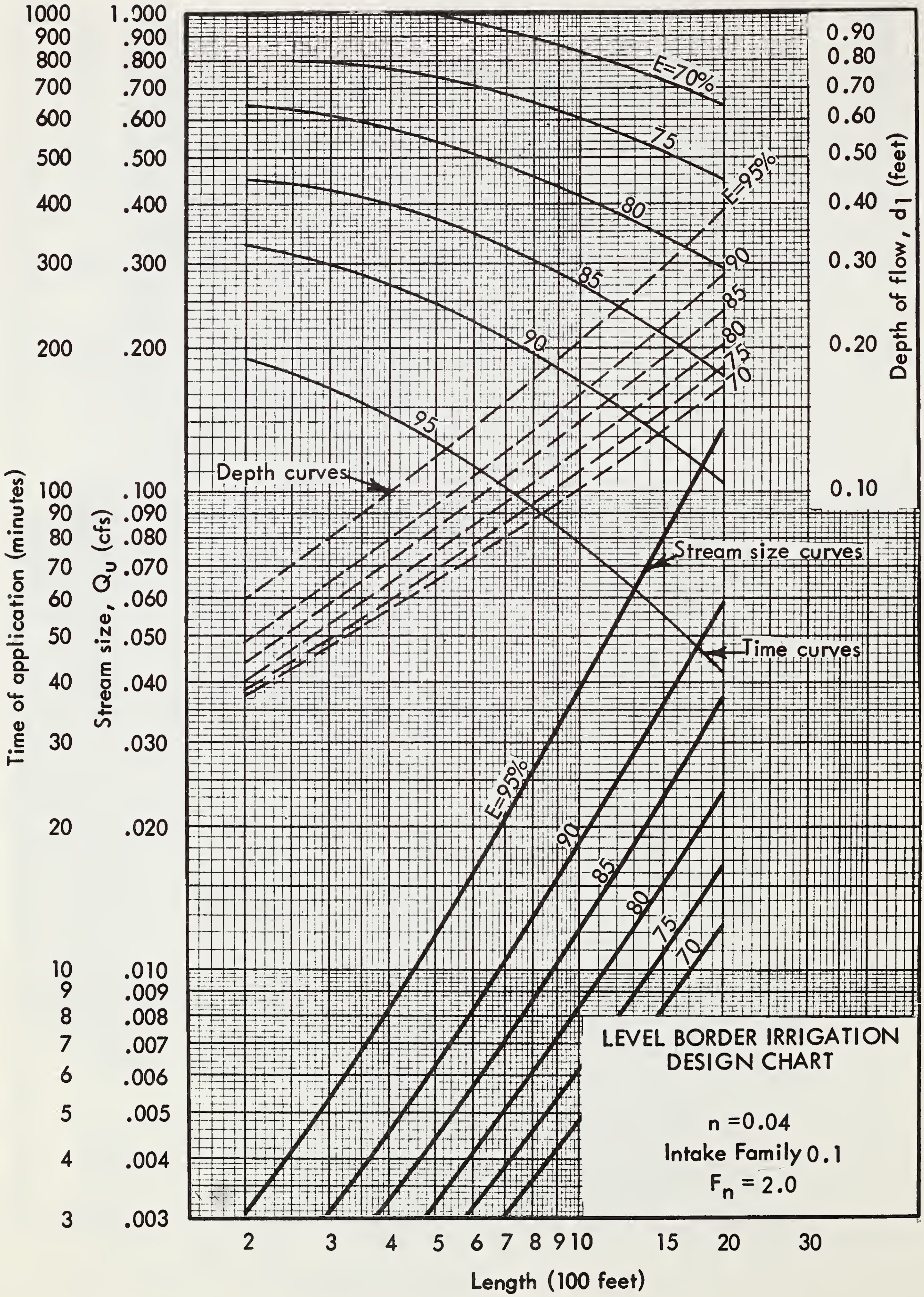
*Not adapted for guide borders. Values are omitted where $F_g > 5F_n$.

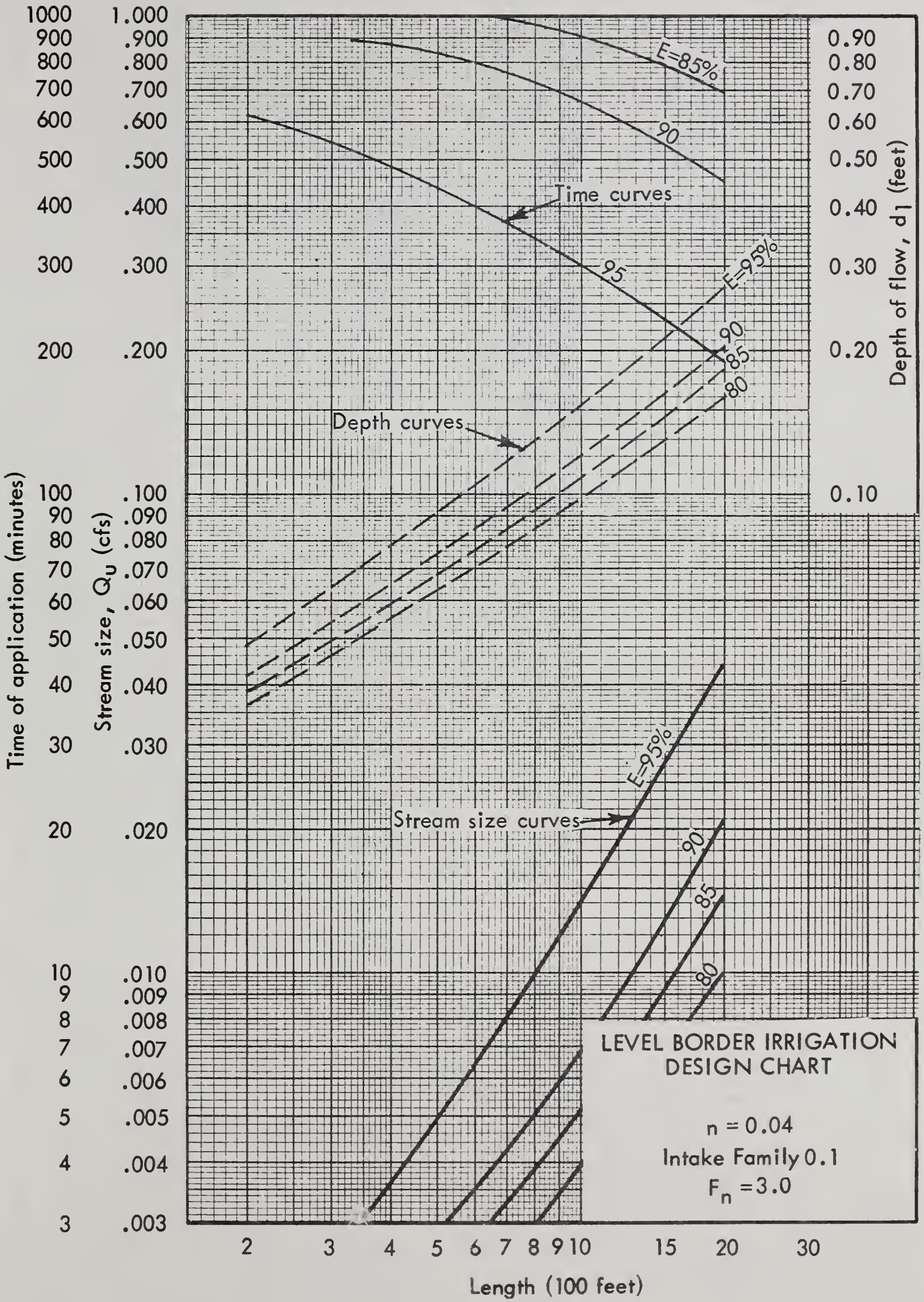
Table 4-18.--Required time of irrigation and gross depth of application for guide borders on 1.0 intake family soils

Irrigation slope	Minimum Q_u/L	$F_n = 1.0$ $T_a = 20$	$F_n = 2.0$ $T_a = 59$	$F_n = 3.0$ $T_a = 106$	$F_n = 4.0$ $T_a = 158$	$F_n = 5.0$ $T_a = 214$
Feet per foot		Gross depth of application (Inches)				
		n = 0.15				
0.0005	0.00000954	*	*	*	*	*
.0010	.00001349	*	*	*	*	*
.0020	.00001908	*	*	*	*	*
.0030	.00002337	*	*	*	*	*
.0040	.00002699	*	*	*	*	*
.0050	.00003017	*	*	*	*	*
.0075	.00003695	*	*	*	*	*
.0100	.00004267	*	*	*	*	*
.0150	.00005227	*	*	*	*	*
.0200	.00006033	*	*	*	*	*
.0250	.00006745	*	*	*	*	10.39
.0300	.00007390	*	*	*	8.41	11.39
.0400	.00008533	*	*	6.51	9.71	13.15
.0500	.00009540	*	4.05	7.28	10.85	14.70
.0600	.00010449	*	4.44	7.97	11.89	16.10
		n = 0.25				
.0005	.00000572	*	*	*	*	*
.0010	.00000810	*	*	*	*	*
.0020	.00001145	*	*	*	*	*
.0030	.00001402	*	*	*	*	*
.0040	.00001619	*	*	*	*	*
.0050	.00001810	*	*	*	*	*
.0075	.00002217	*	*	*	*	*
.0100	.00002560	*	*	*	*	*
.0150	.00003136	*	*	*	*	*
.0200	.00003620	*	*	*	*	*
.0250	.00004047	*	*	*	*	*
.0300	.00004434	*	*	*	*	*
.0400	.00005120	*	*	*	*	*
.0500	.00005724	*	*	*	*	*
.0600	.00006270	*	*	*	*	*

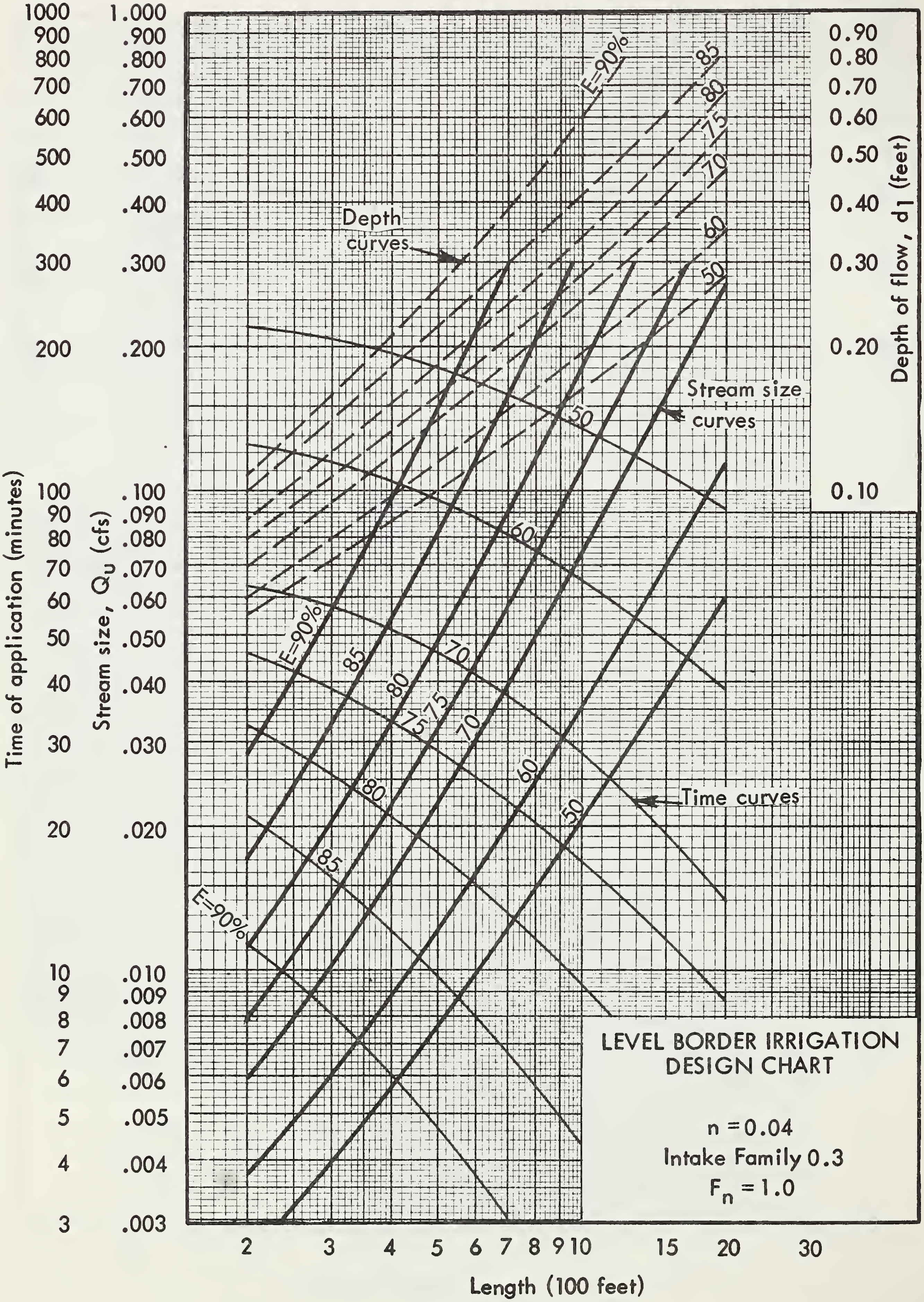
*Not adapted for guide borders.


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=95%
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.1
F_n = 1.0

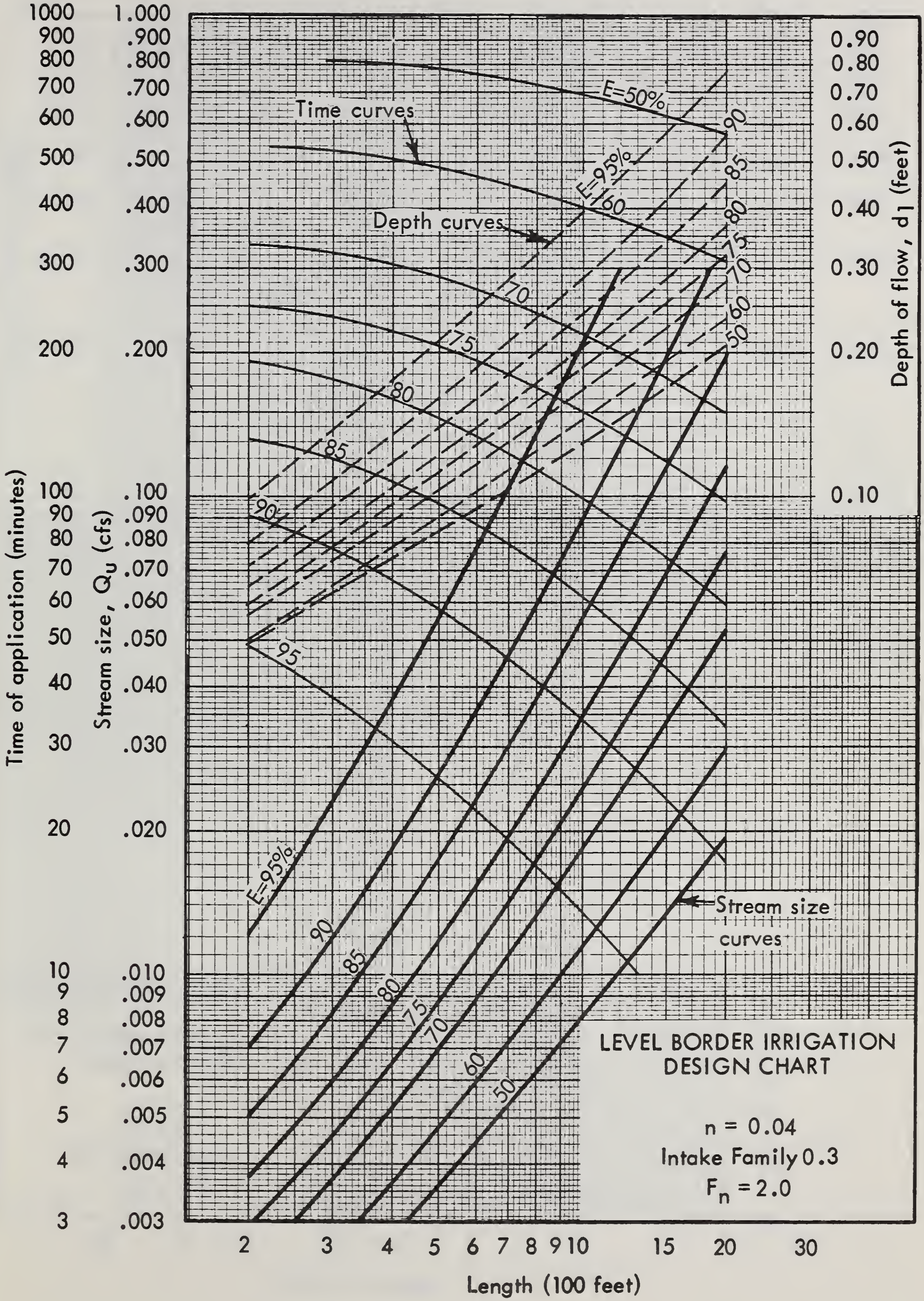

LEVEL BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 0.1
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=70%
75
80
85
90
95
E=95%
70
E=95%
90
85
80
75
70
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30



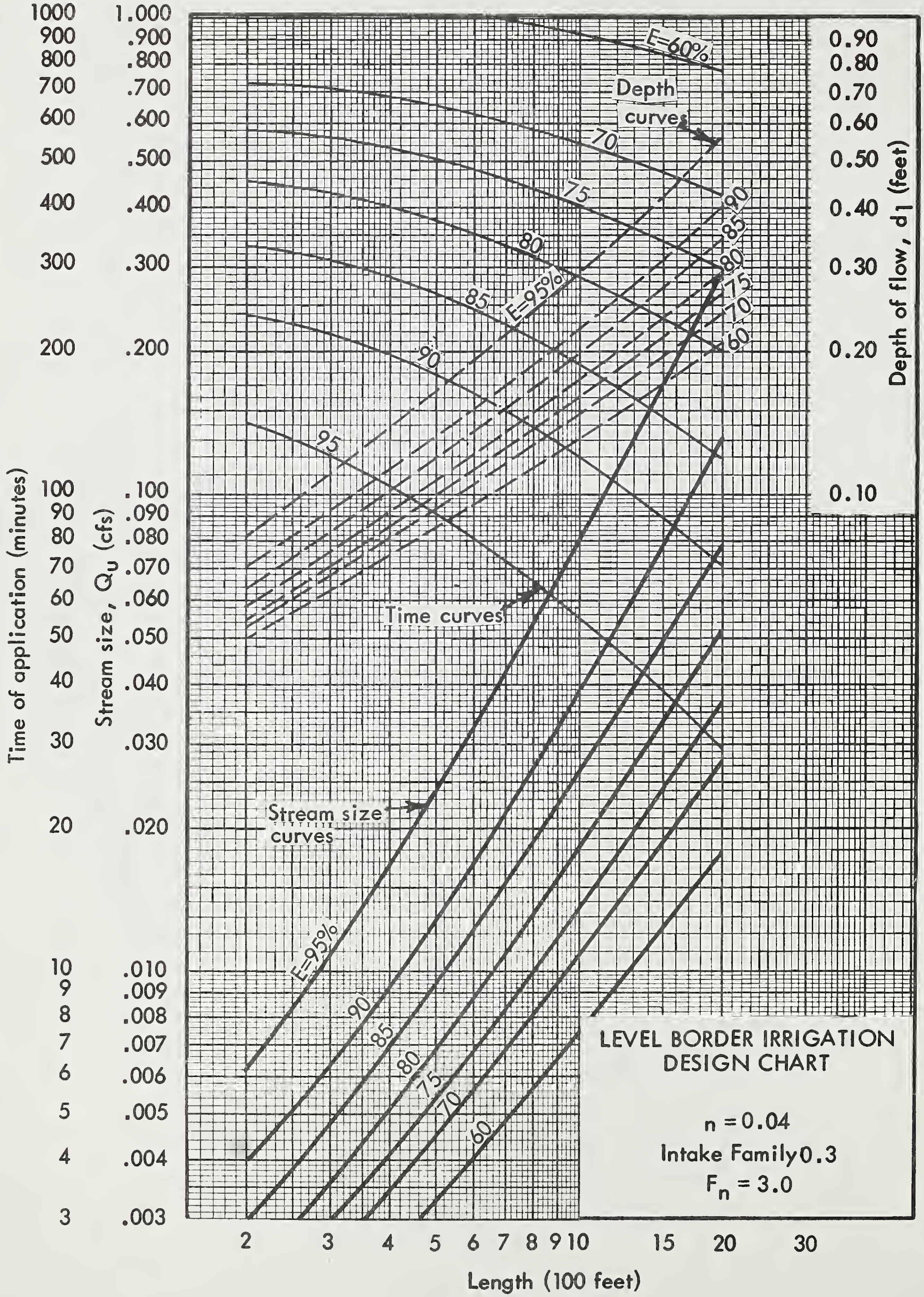
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.1
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=85%
90
95
E=95%
90
85
80
E=95%
90
85
80
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30



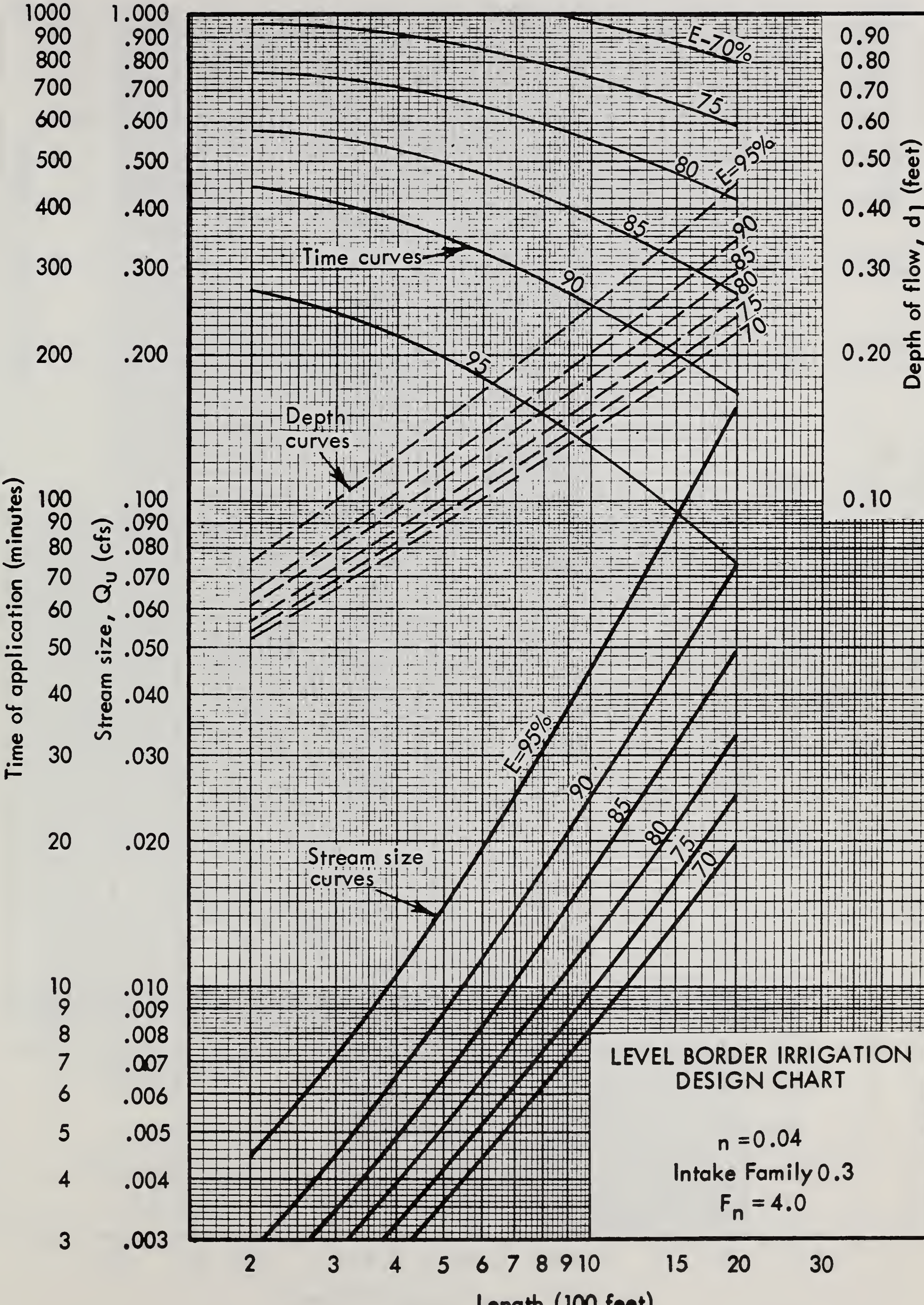
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.3
F_n = 1.0



Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Time curves
Depth curves
Stream size curves
E=50%
E=95%
E=95%
90
85
80
75
70
60
50
95
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.3
F_n = 2.0

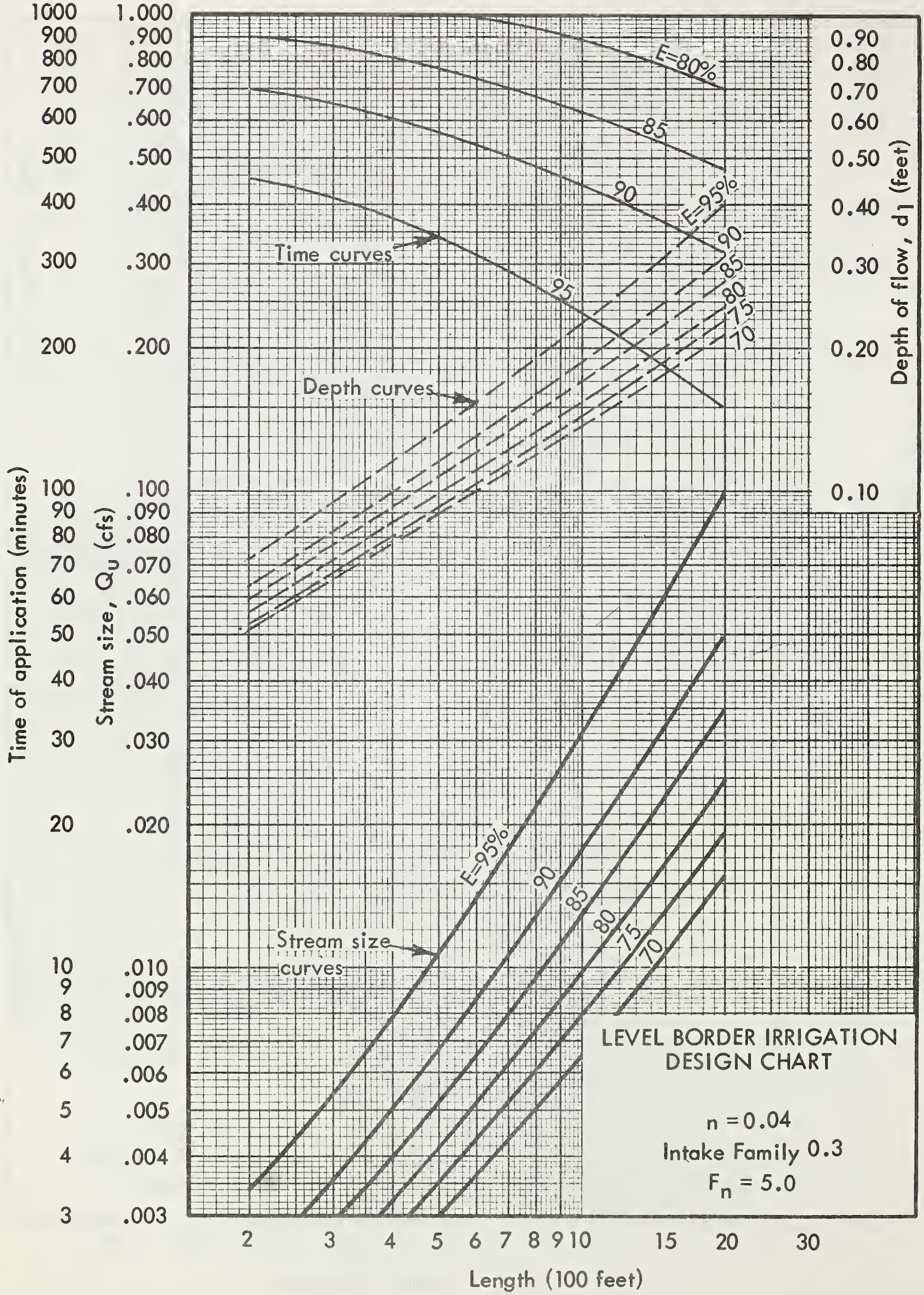


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=60%
Depth curves
70
75
80
85
90
95
E=95%
Time curves
Stream size curves
60
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.3
F_n = 3.0

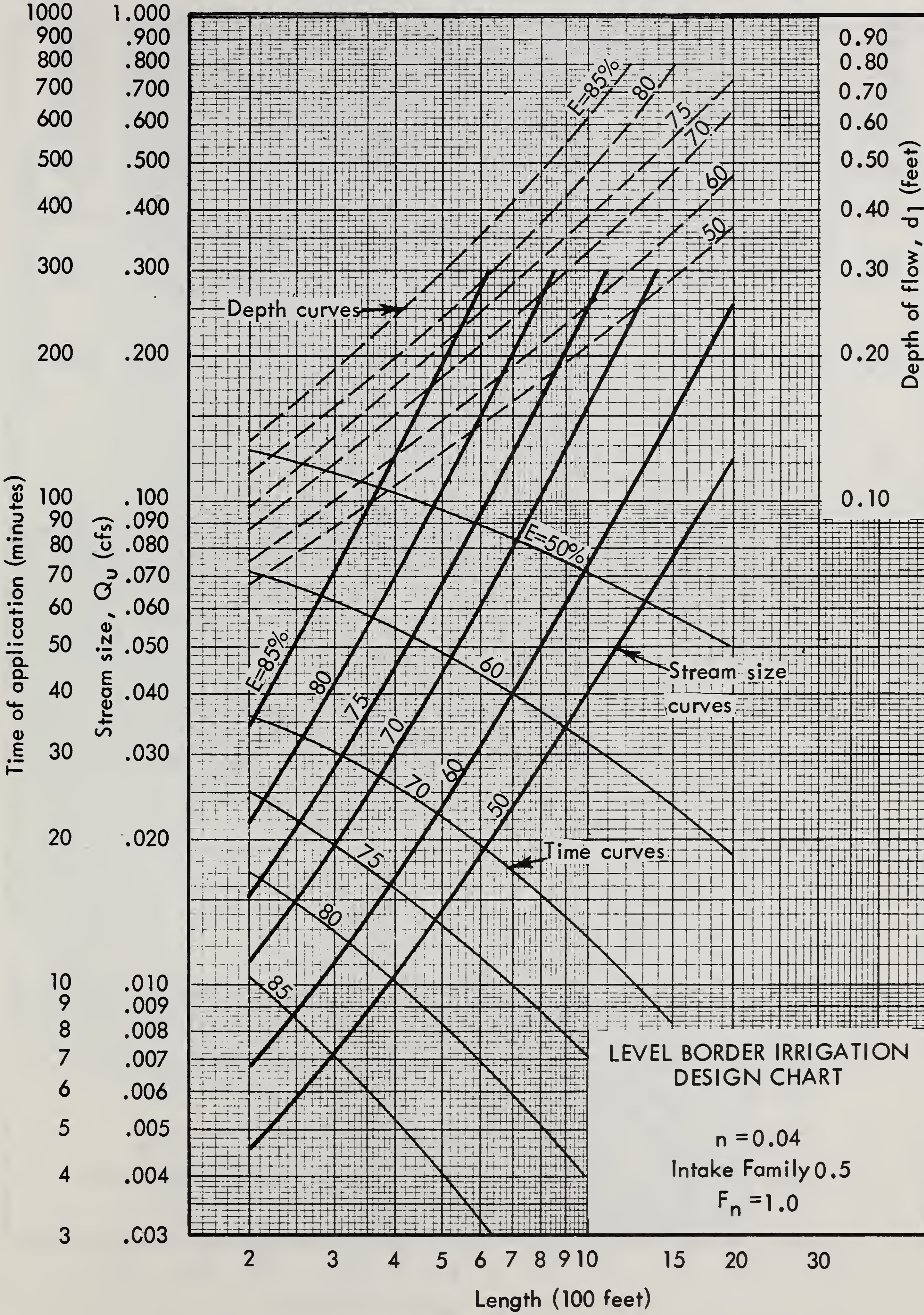


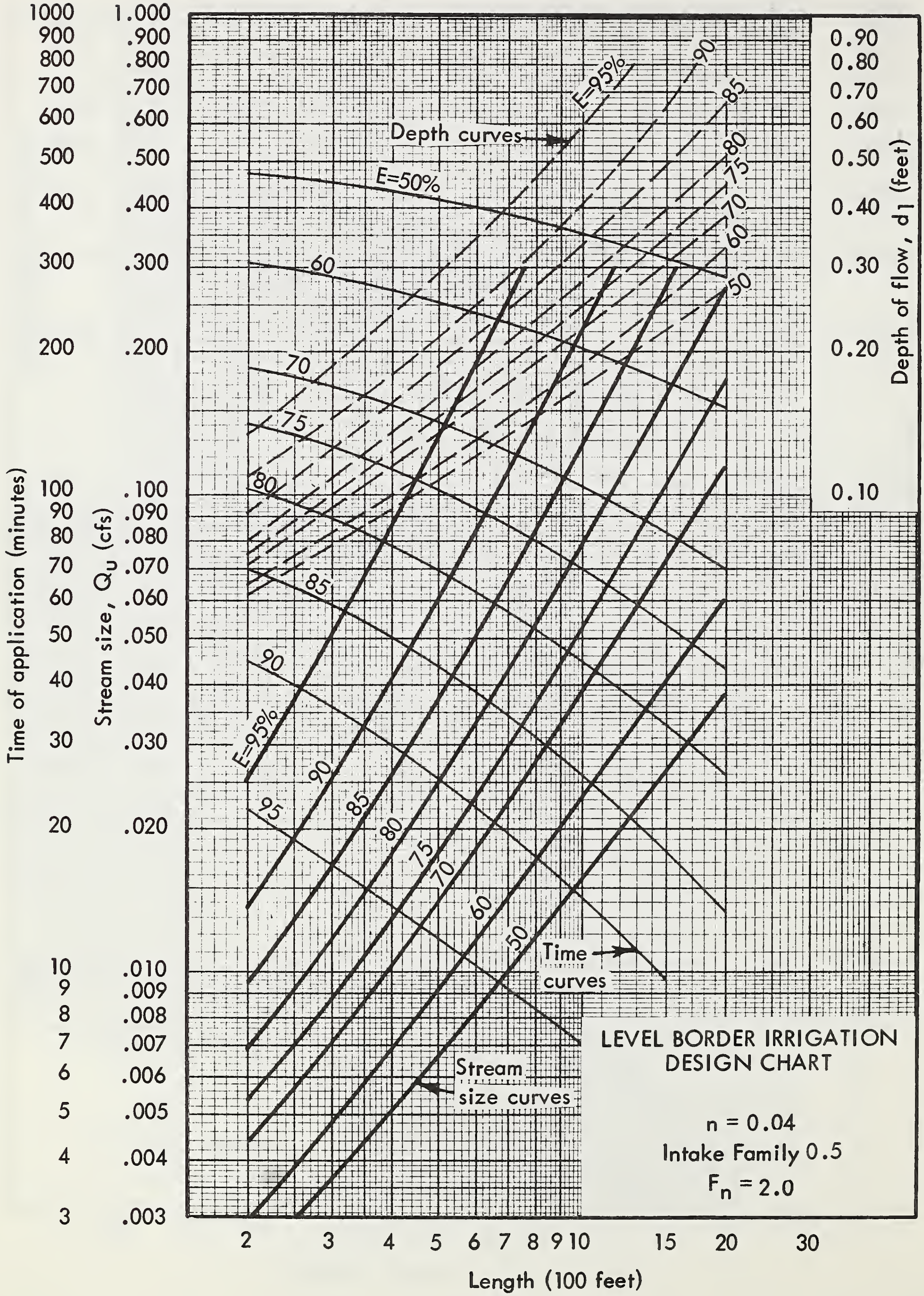
LEVEL BORDER IRRIGATION DESIGN CHART

$n = 0.04$
Intake Family 0.3
$F_n = 4.0$

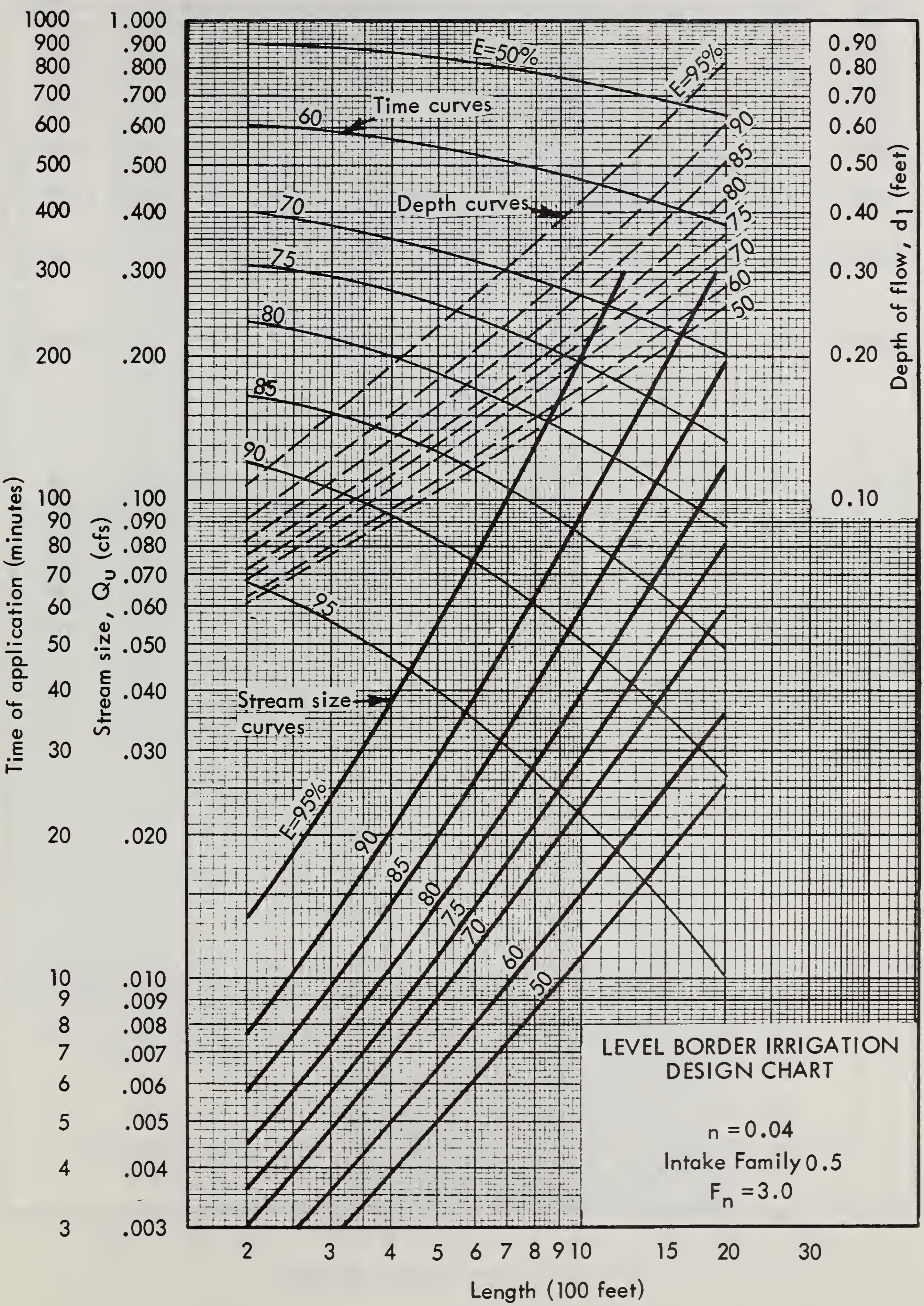


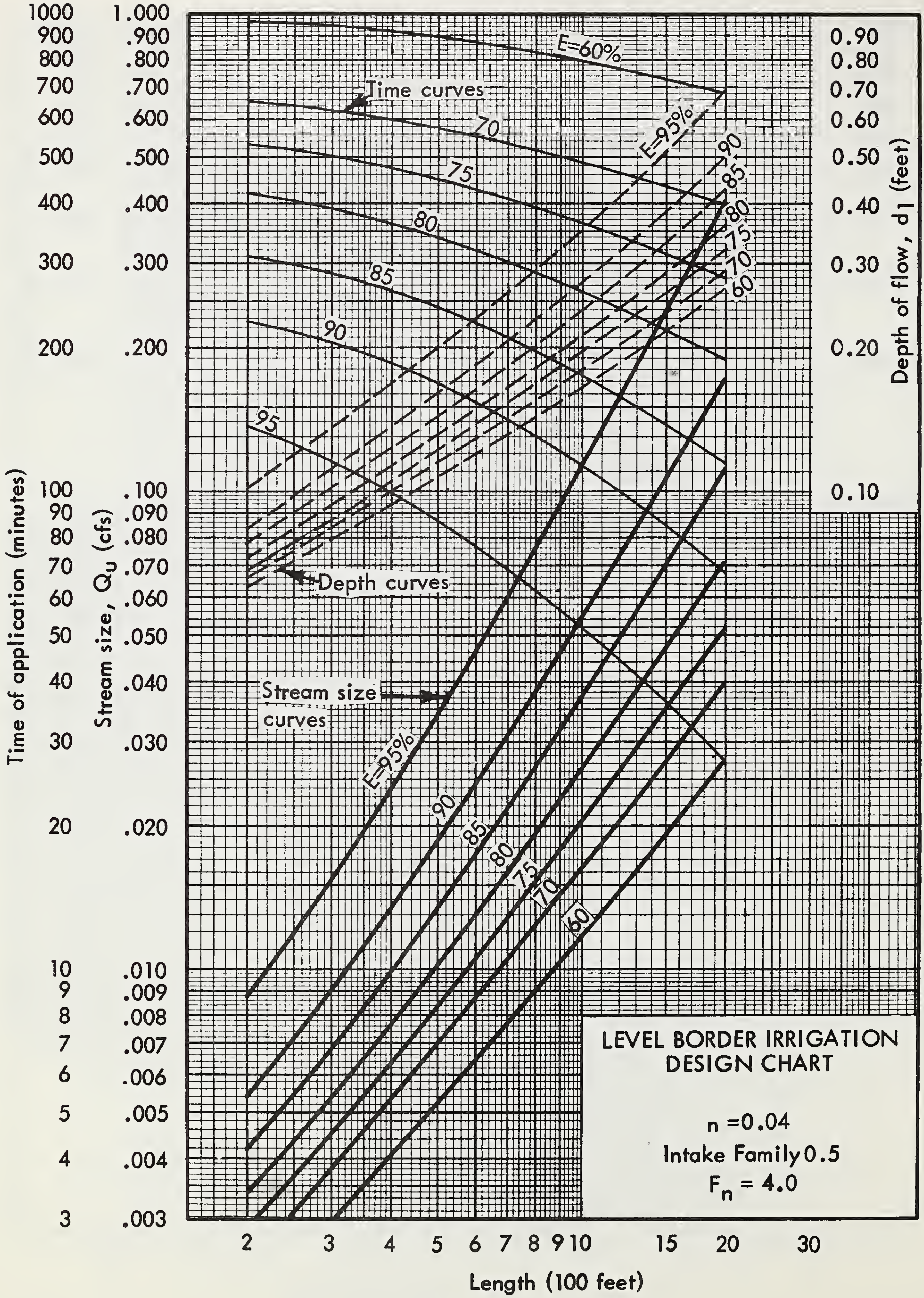
1000 1.000
900 .900
800 .800
700 .700
600 .600
500 .500
400 .400
300 .300
200 .200
100 .100
90 .090
80 .080
70 .070
60 .060
50 .050
40 .040
30 .030
20 .020
10 .010
9 .009
8 .008
7 .007
6 .006
5 .005
4 .004
3 .003
Time of application (minutes)
Stream size, Q_u (cfs)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth of flow, d_1 (feet)
E=80%
85
90
95
E=95%
90
85
80
75
70
Time curves
Depth curves
Stream size curves
E=95%
90
85
80
75
70
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.3
F_n = 5.0
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 1.0

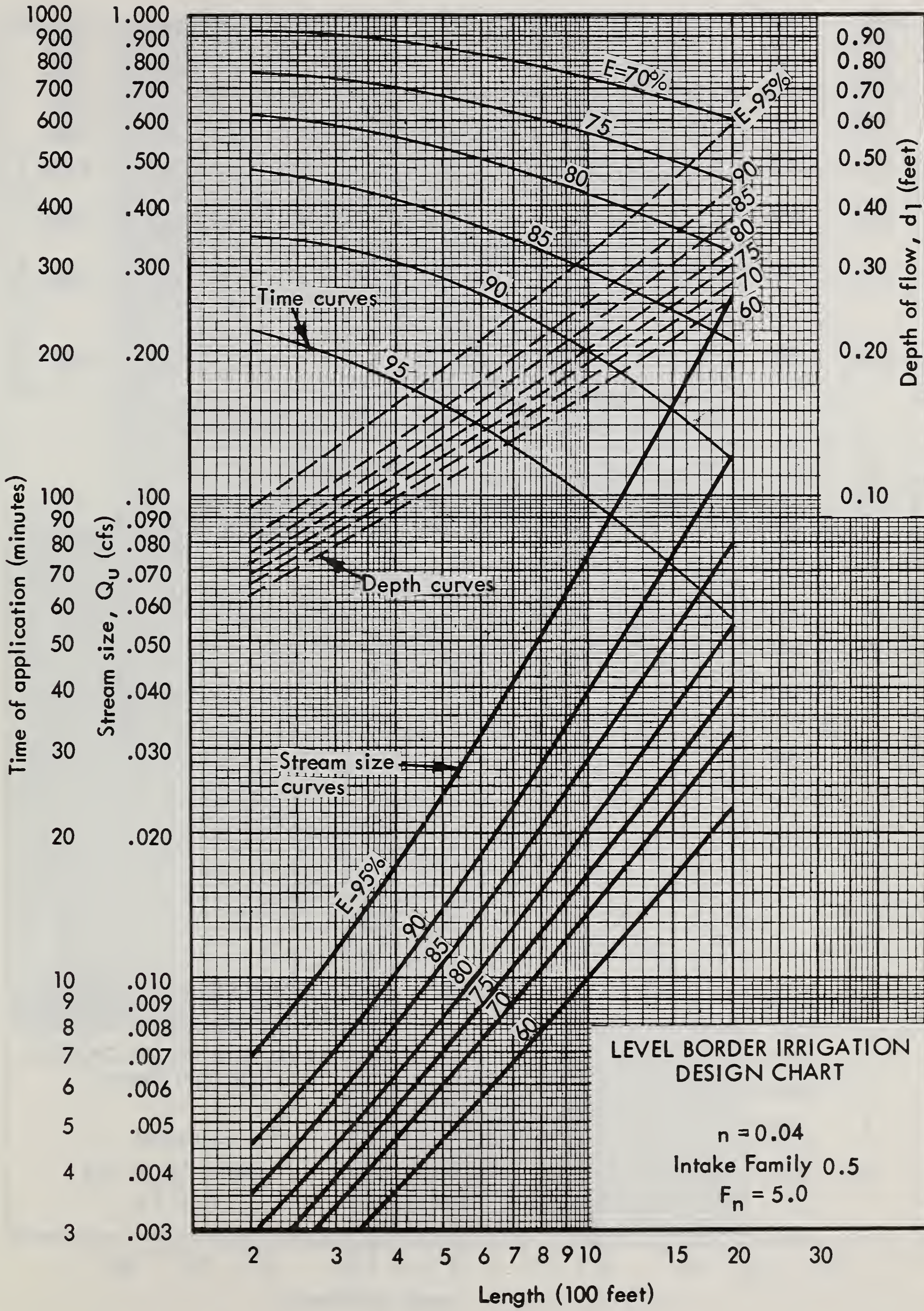


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=50%
E=95%

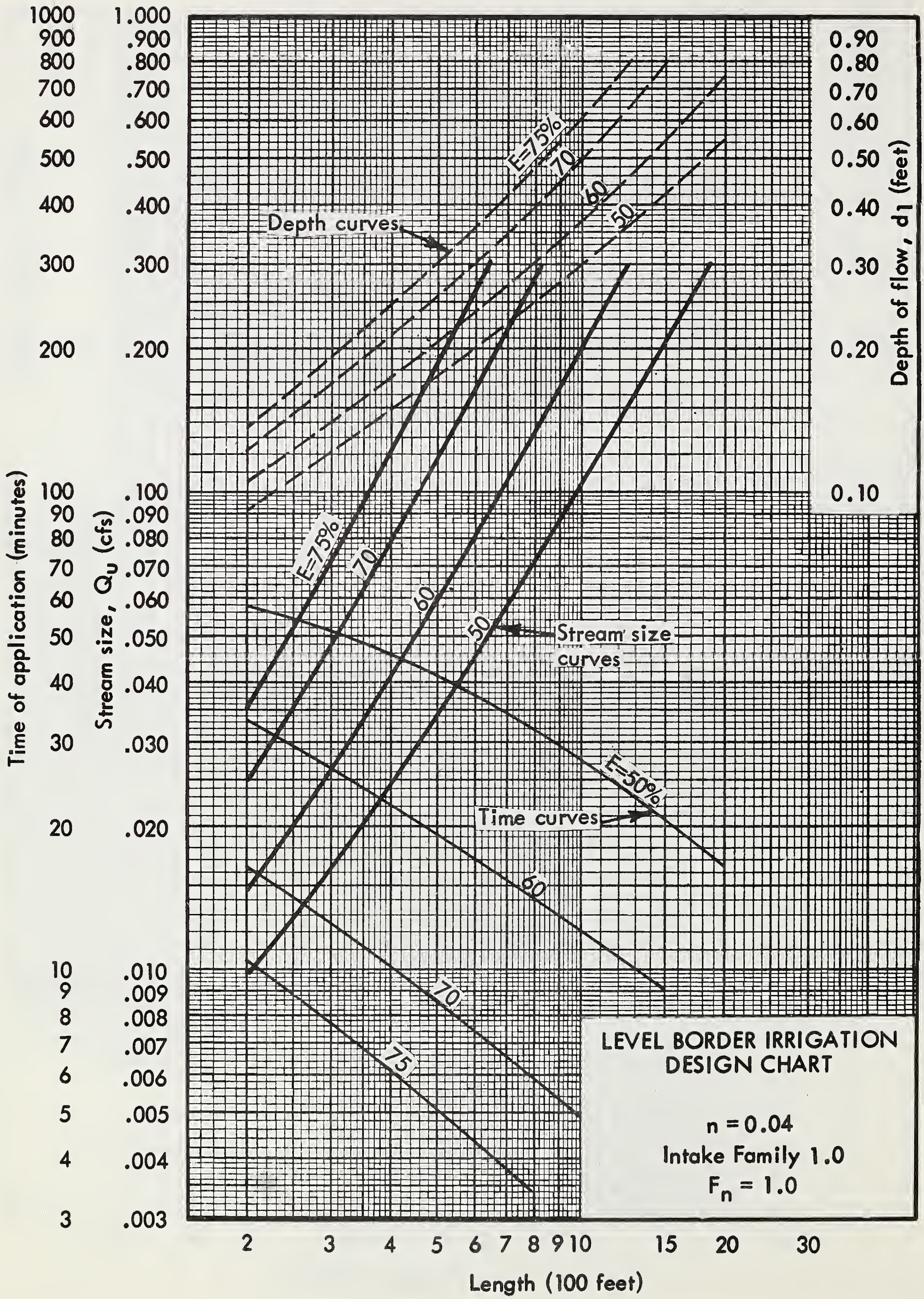

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=50%
E=95%
Time curves
Depth curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 3.0

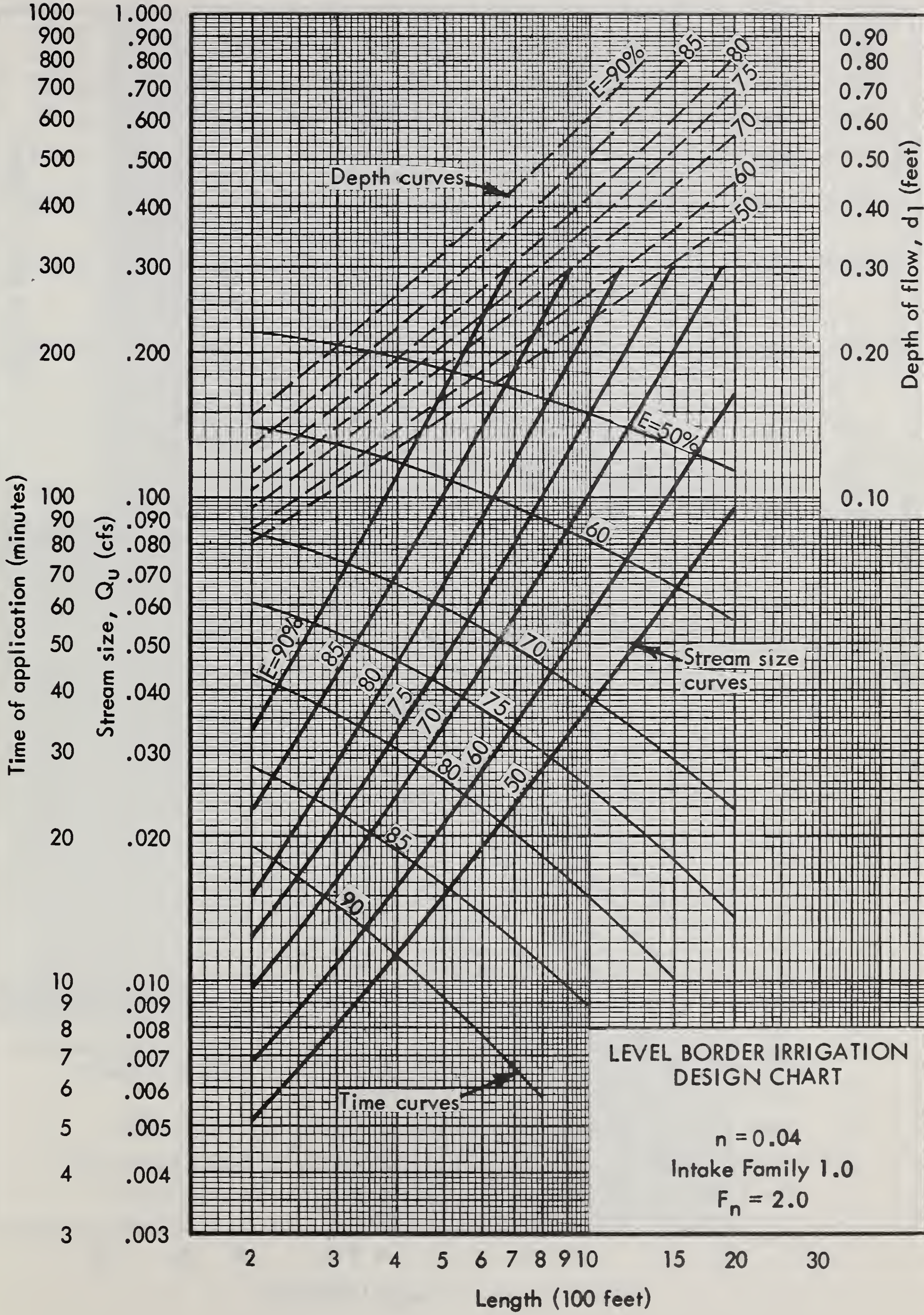


Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=60%
Time curves
70
75
80
85
90
95
E=95%
90
85
80
75
70
60
Depth curves
Stream size curves
E=95%
90
85
80
75
70
60
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 0.5
F_n = 4.0
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)

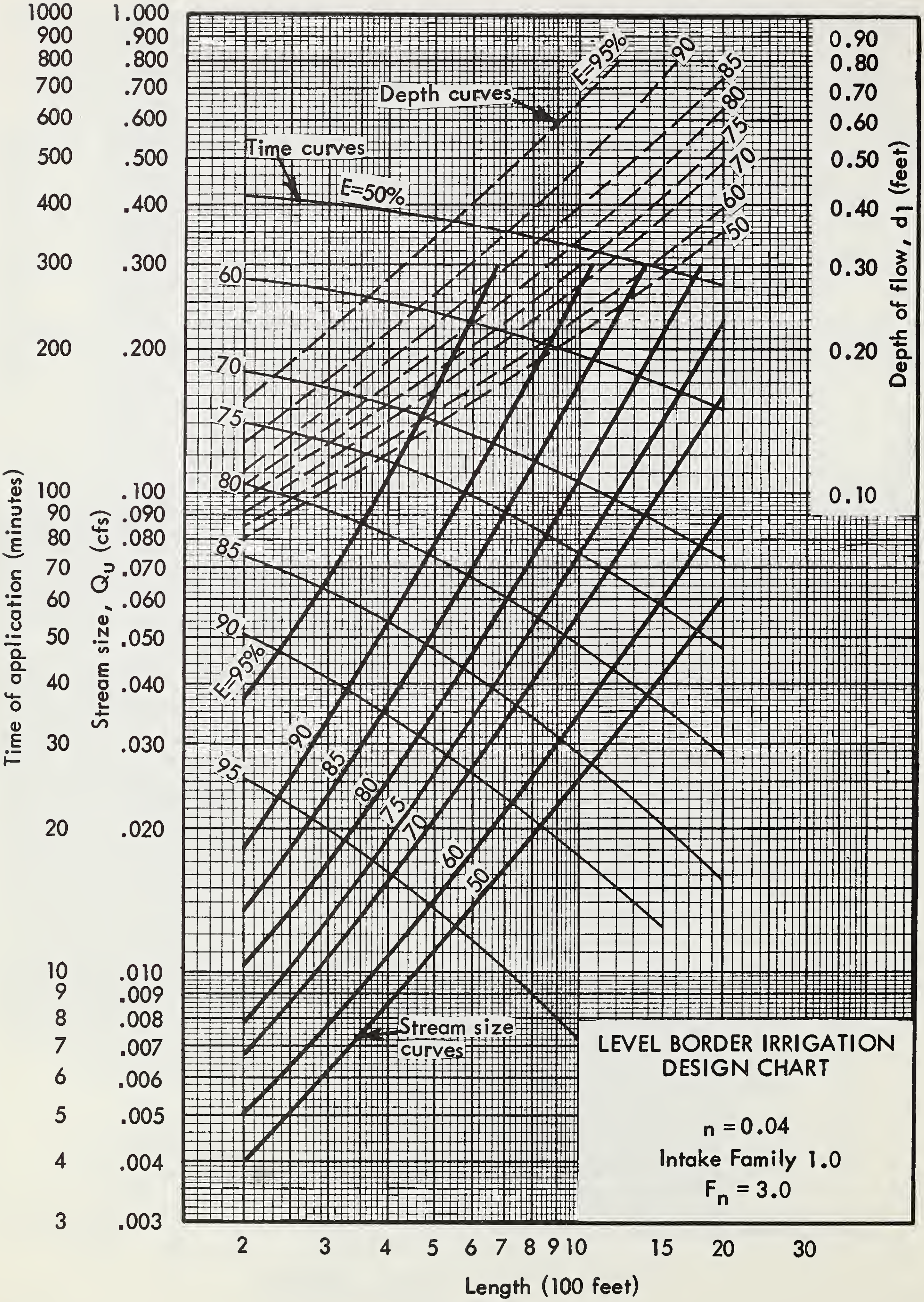


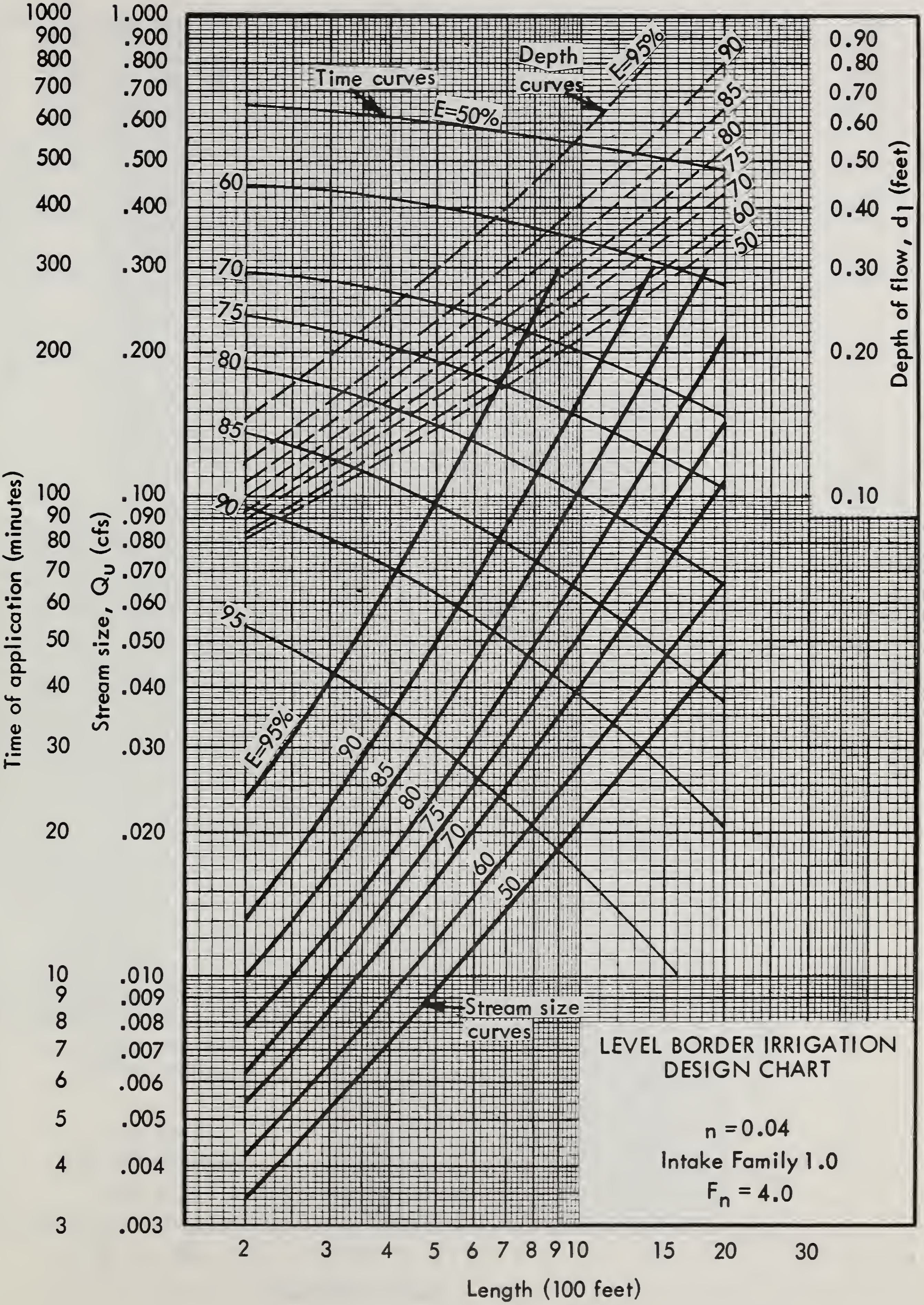
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=70%
75
80
85
90
95
E-95%
60
70
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30


Time of application (minutes)
Stream size, Q_U (cfs)
Depth of flow, d_1 (feet)
Depth curves
E=75%
70
60
50
Stream size curves
E=75%
70
60
50
Time curves
E=50%
60
70
75
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 1.0
Length (100 feet)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30

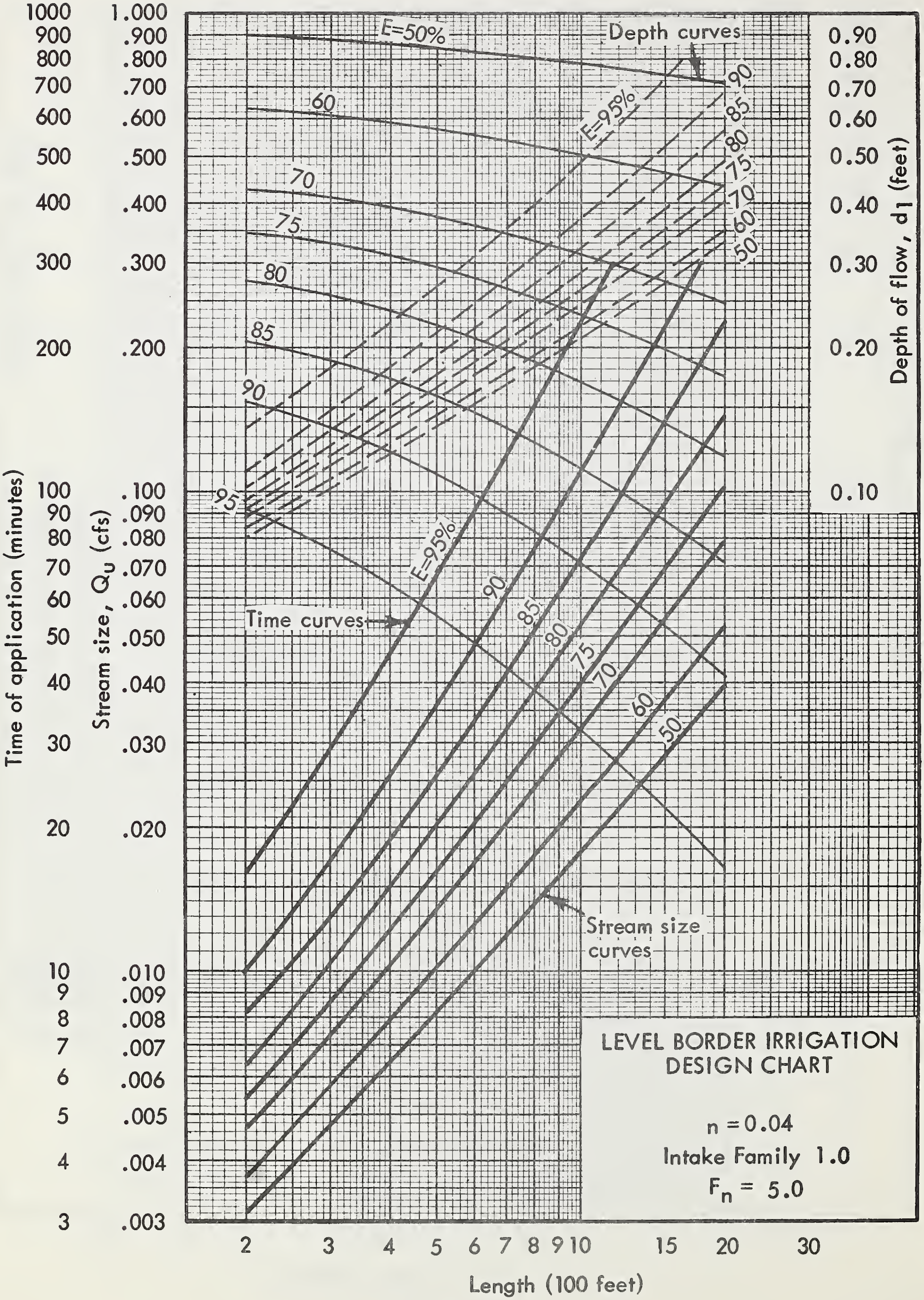


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
85
80
75
70
60
50
E=50%
90
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 2.0

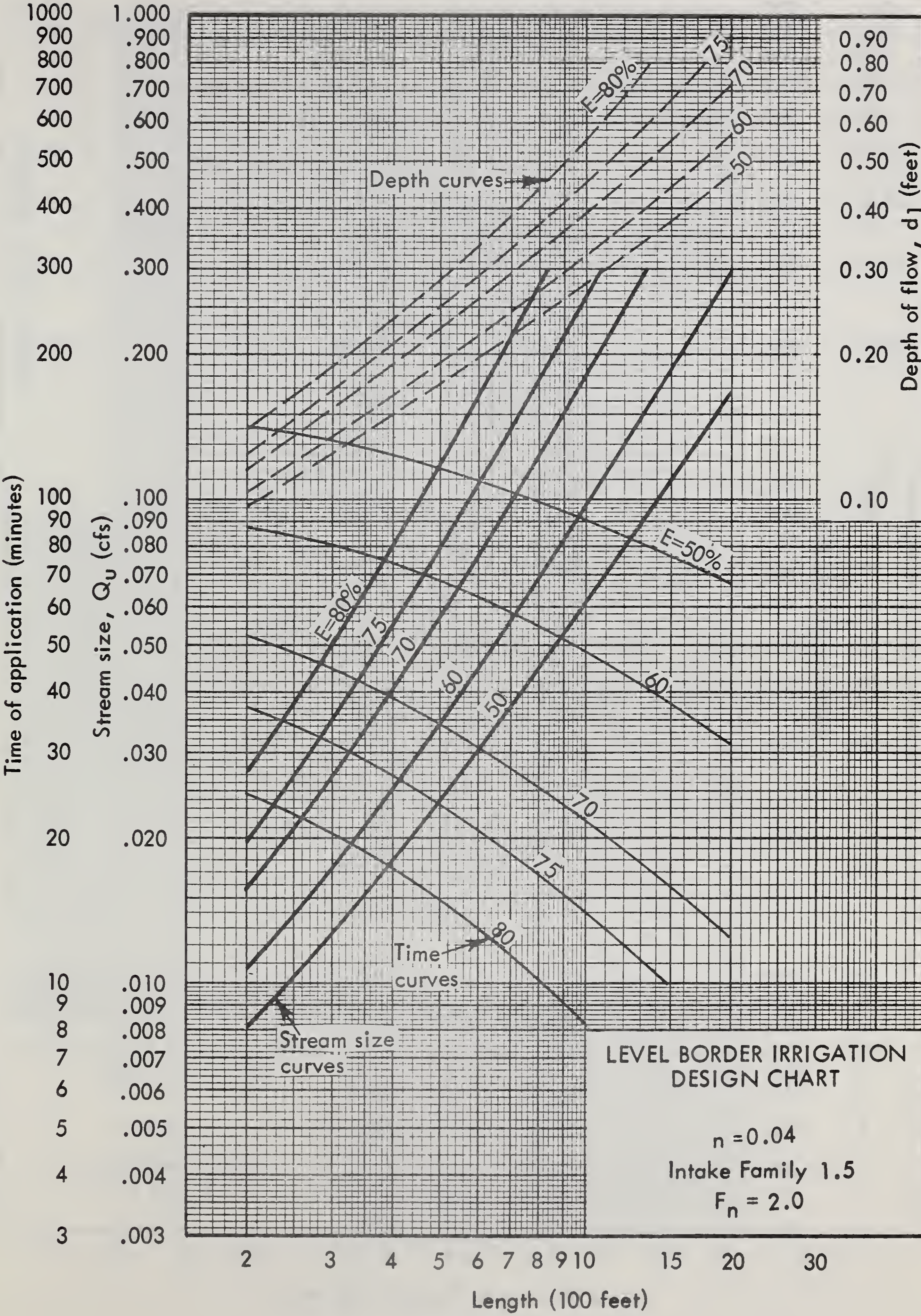

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
E=50%
E=95%
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 3.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=50%
E=95%
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 4.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=50%
Depth curves
E=95%
Time curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 5.0



LEVEL BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 1.5
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=80%
75
70
60
50
E=50%
80
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
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4
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1.000
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.040
.030
.020
.010
.009
.008
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.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
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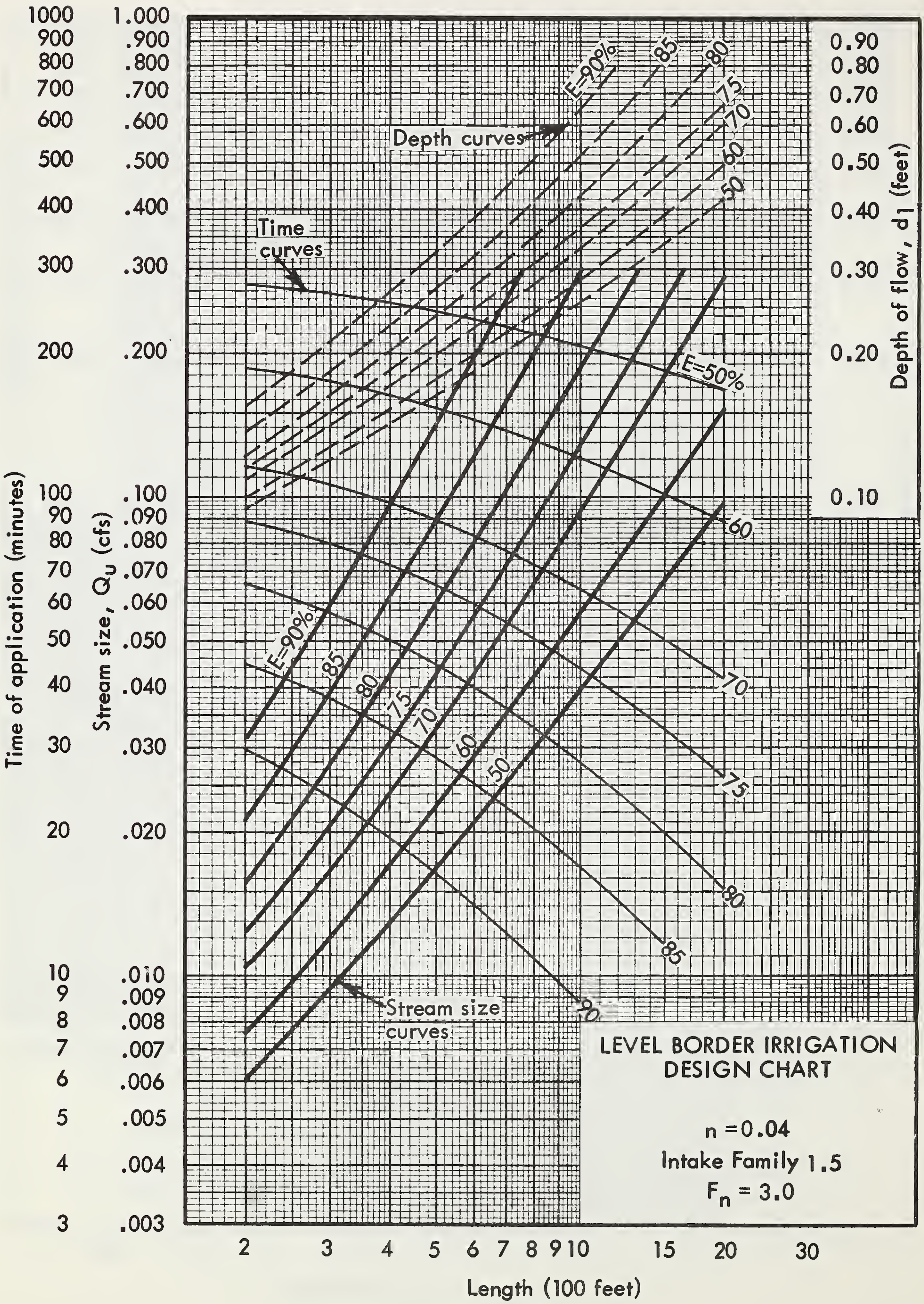
6
7
8
9
10
15
20
30



Time of application (minutes)
1000
900
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700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
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.009
.008
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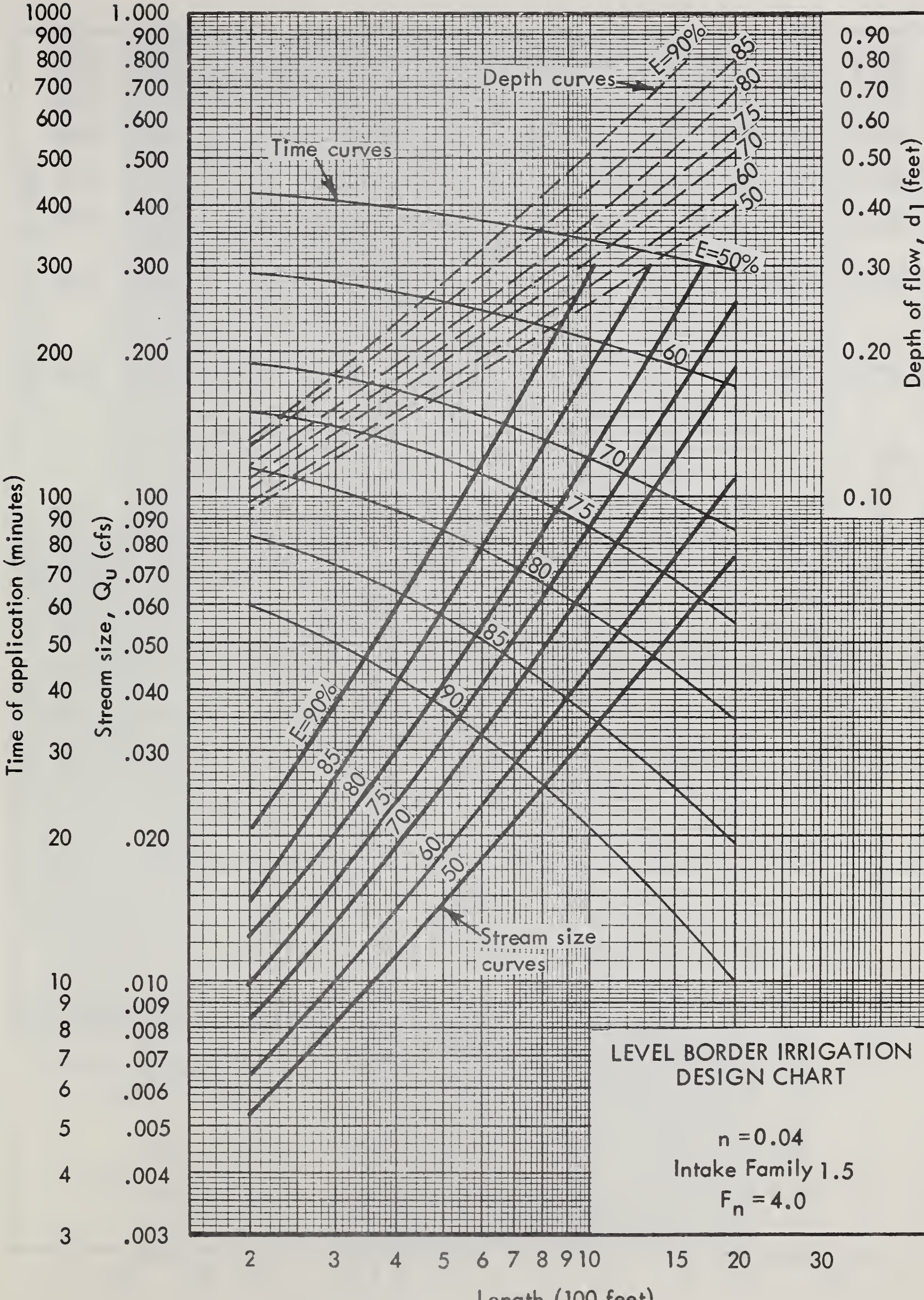
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
Time curves
Stream size curves
E=90%
85
80
75
70
60
50
E=50%
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION
DESIGN CHART
n =0.04
Intake Family 1.5
F_n = 3.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=90%
E=50%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
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20
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0.90
0.80
0.70
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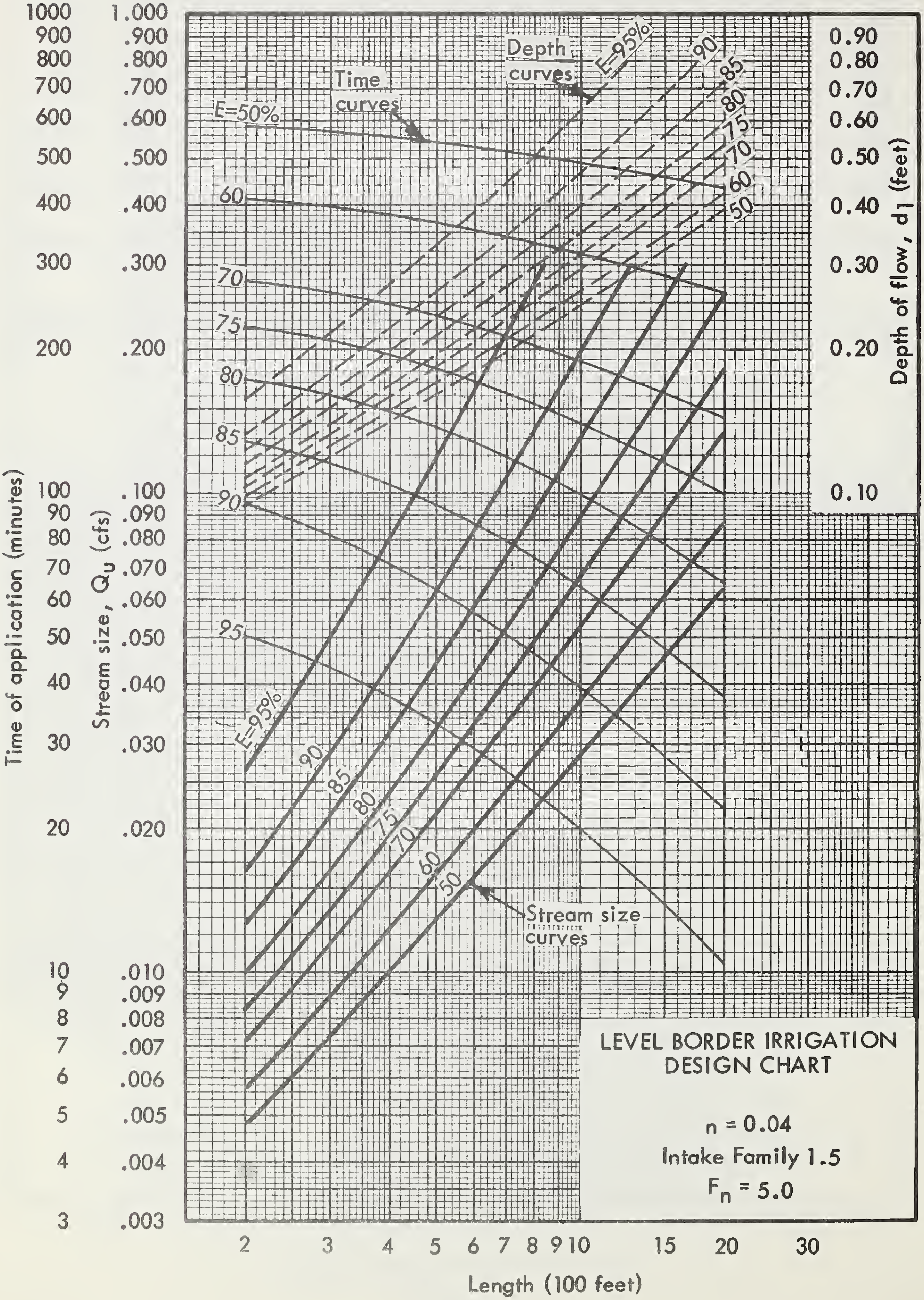

Time of application (minutes)
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Stream size, Q_u (cfs)
1.000
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.040
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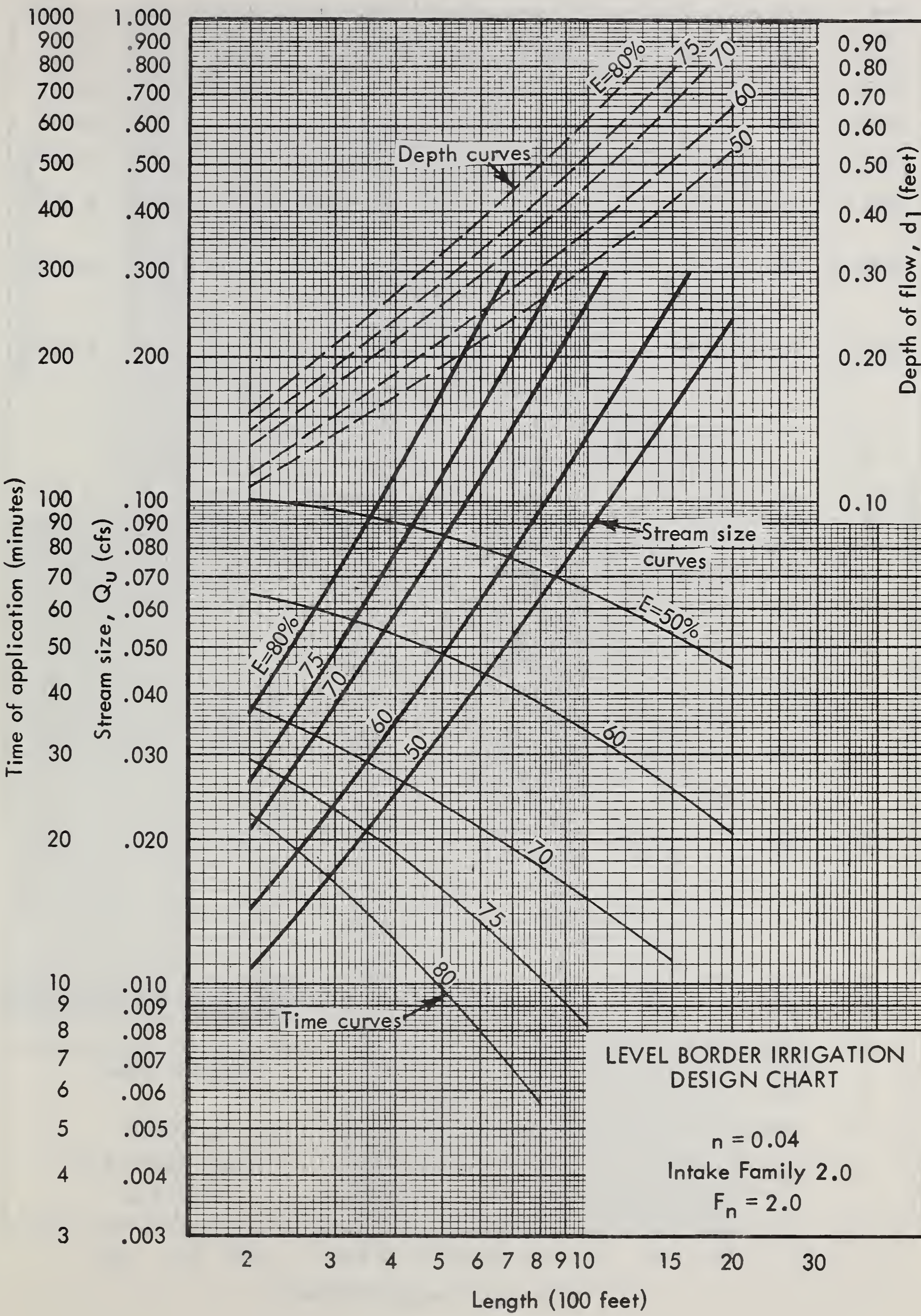
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Time curves
Depth curves
Stream size curves
E=50%
60
70
75
80
85
90
95
E=95%
90
85
80
75
70
60
50
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 5.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
80
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
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.003
0.90
0.80
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0.60
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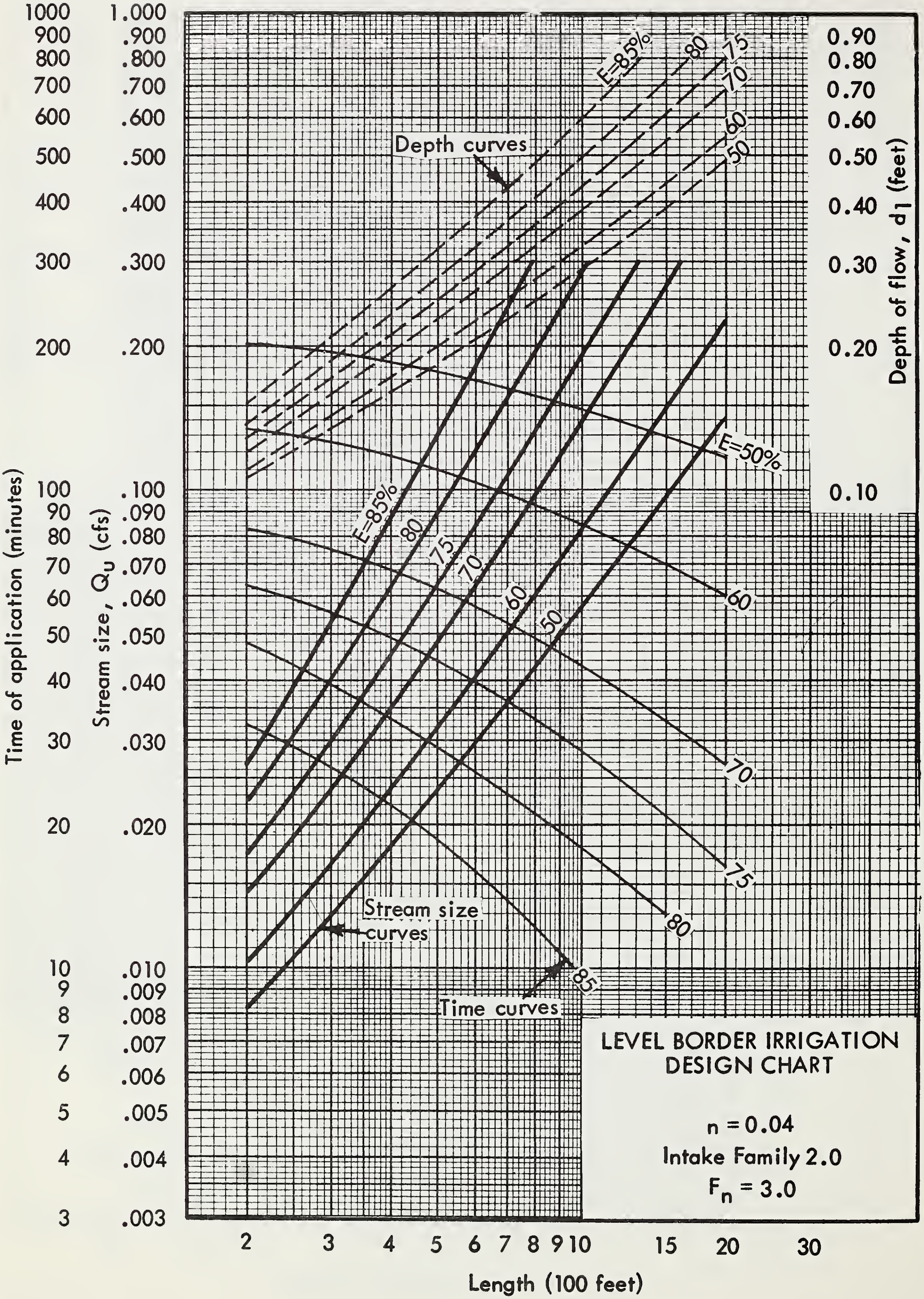

LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
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30
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.004
.003
0.90
0.80
0.70
0.60
0.50
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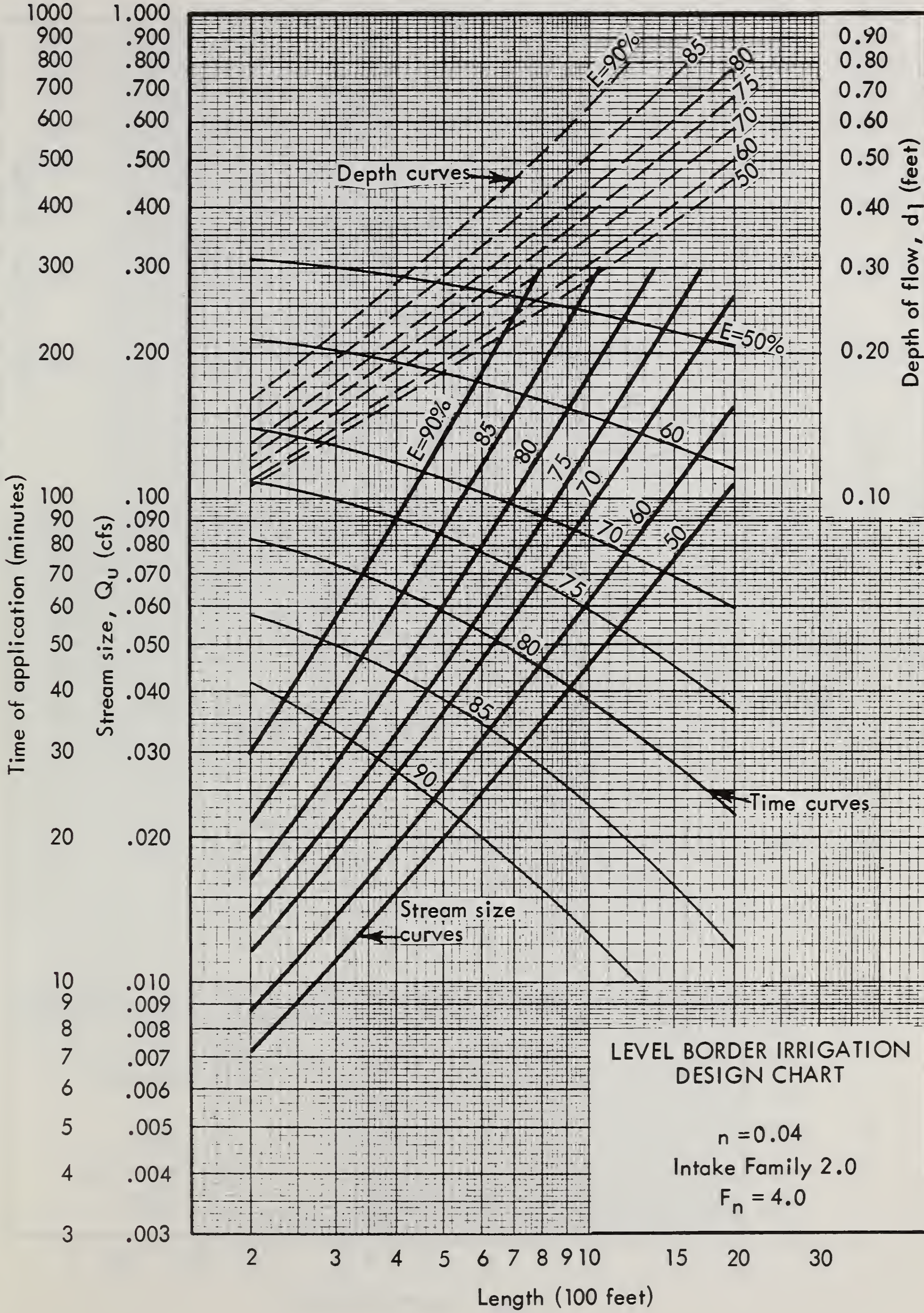
LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size
curves
E=90%
85
80
75
70
60
50
E=50%
90
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
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30
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.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
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0.10
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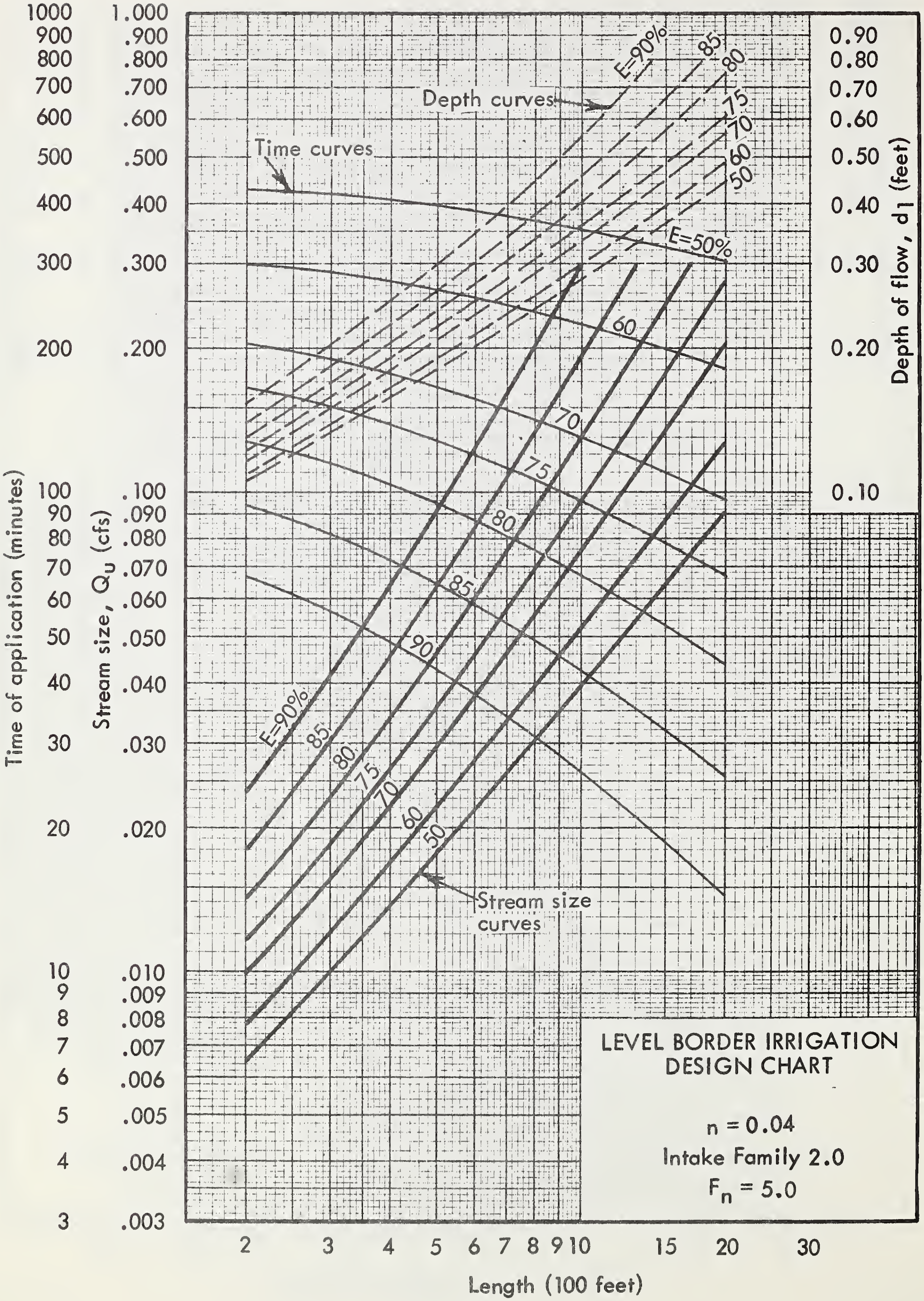

Time of application (minutes)
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100
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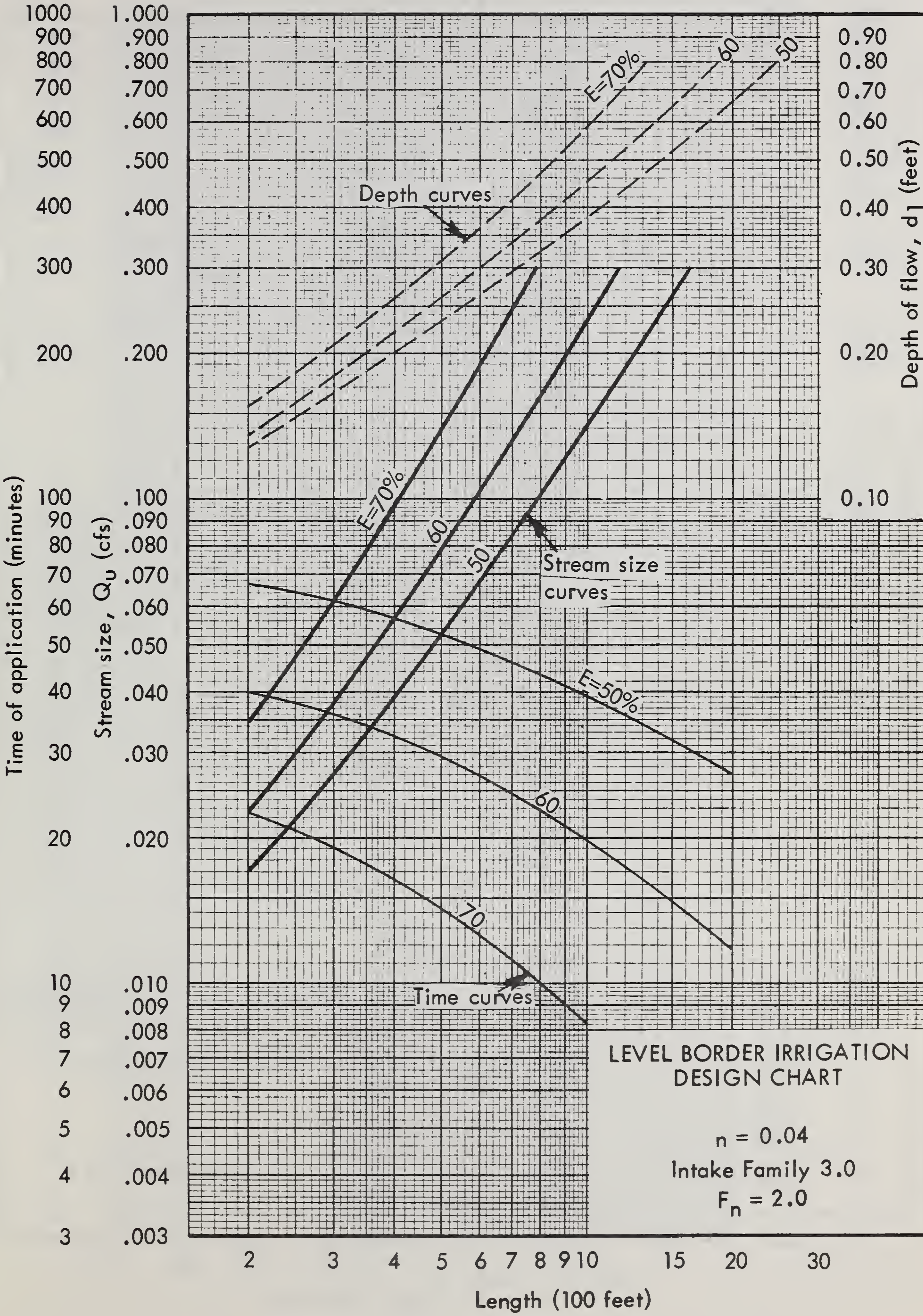
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
Time curves
Stream size curves
E=90%
85
80
75
70
60
50
E=50%
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 5.0



Time of application (minutes)
1000
900
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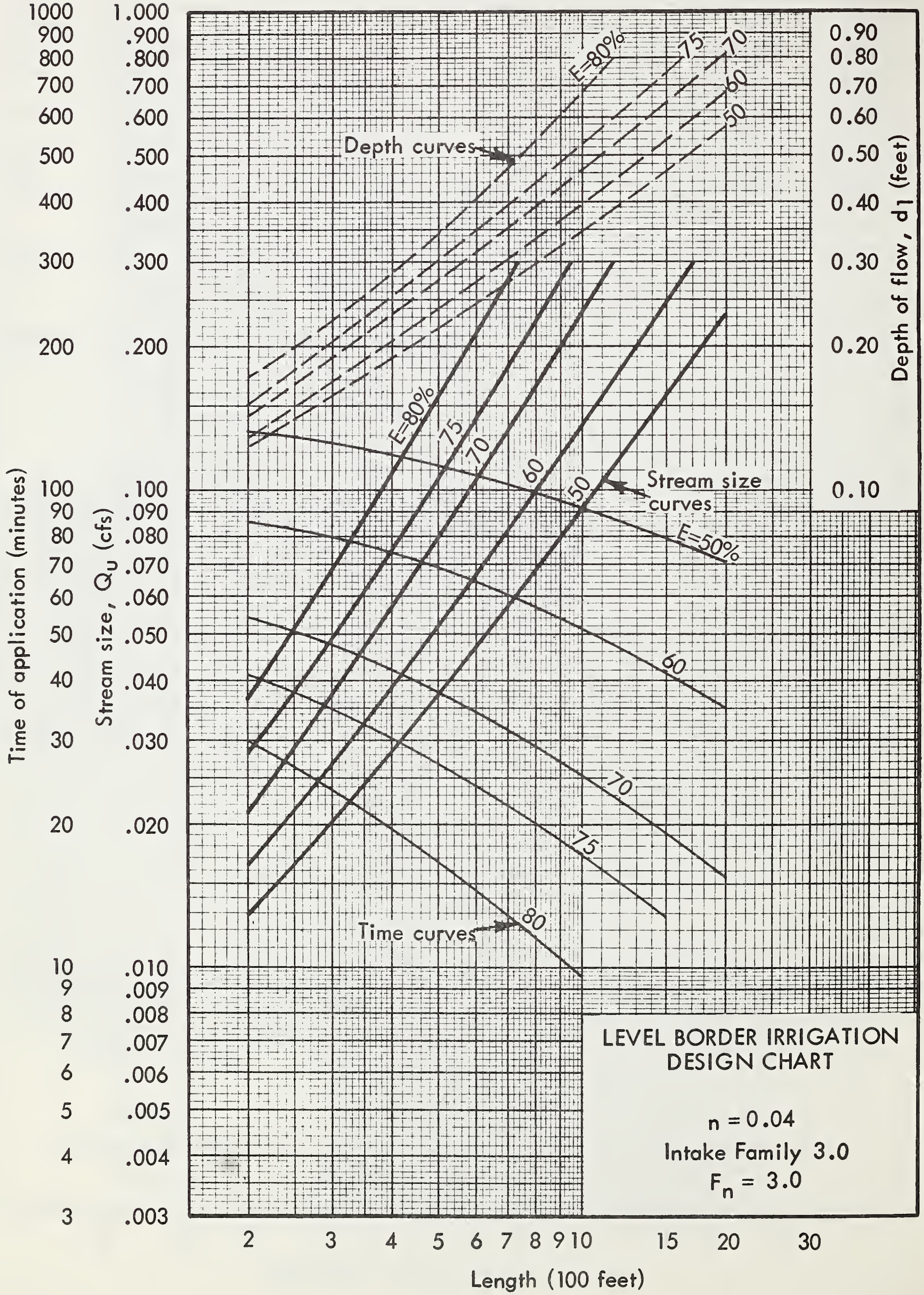
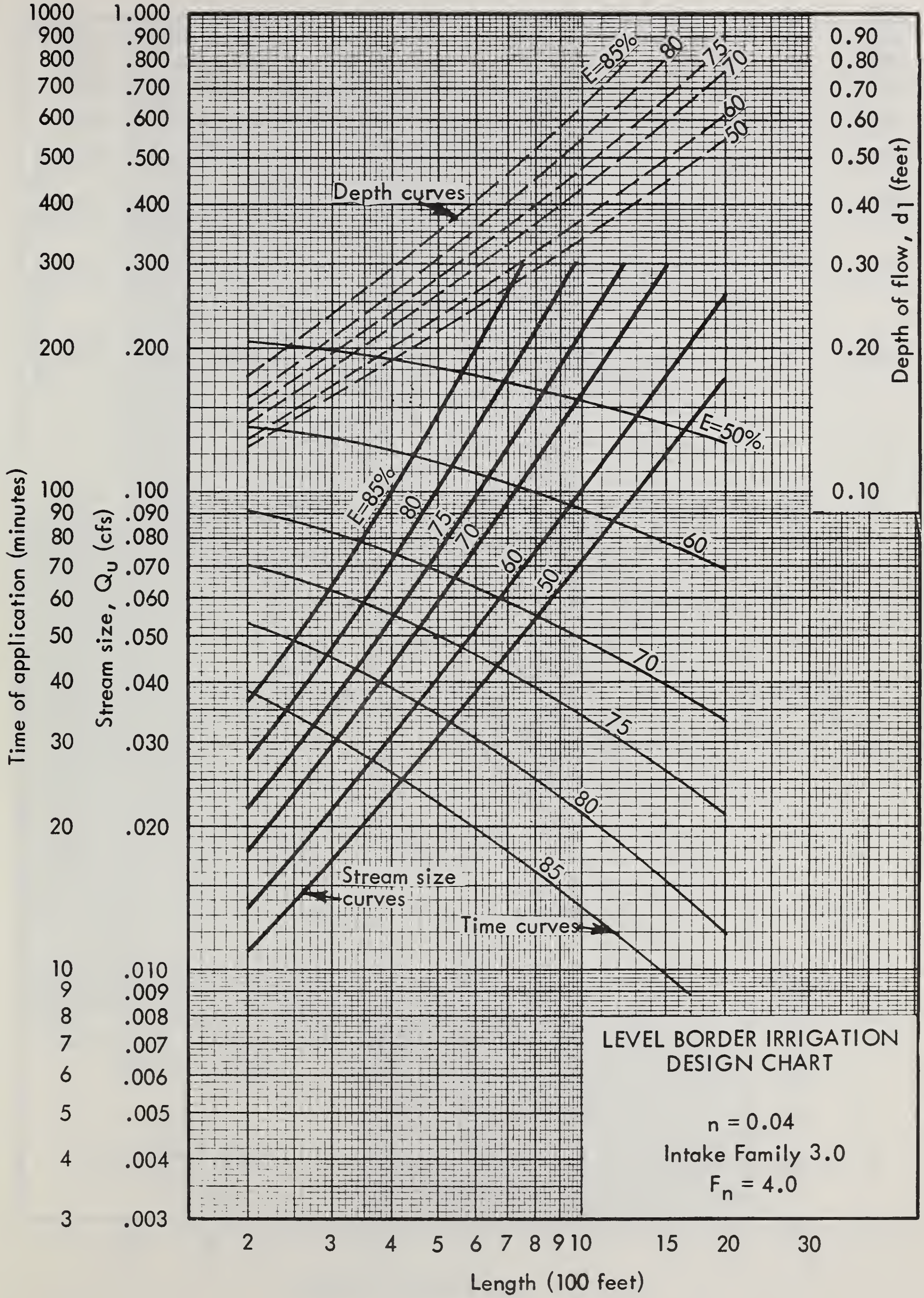
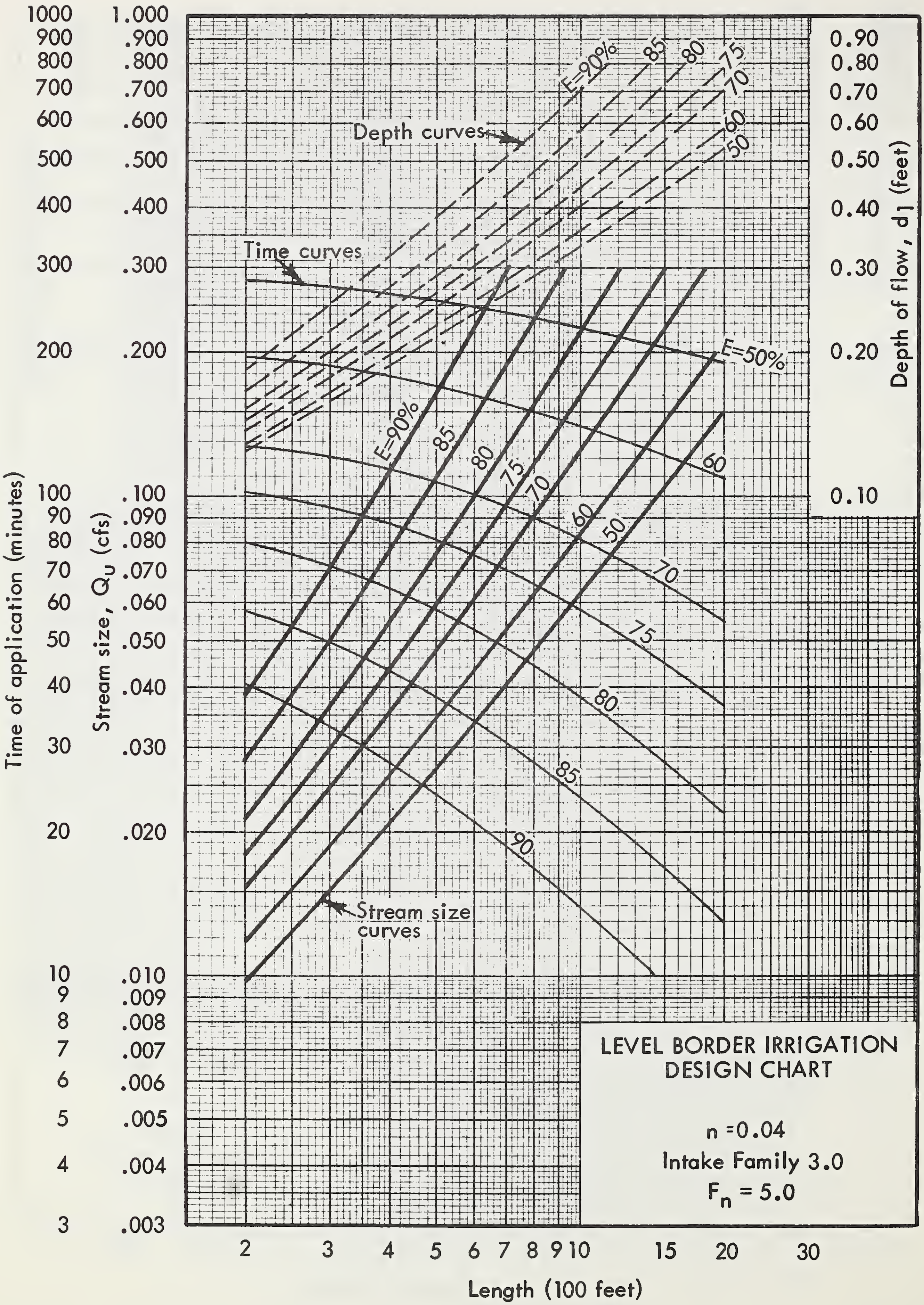
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
E=70%
60
50
Stream size curves
E=70%
60
50
Time curves
E=50%
60
70
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 2.0



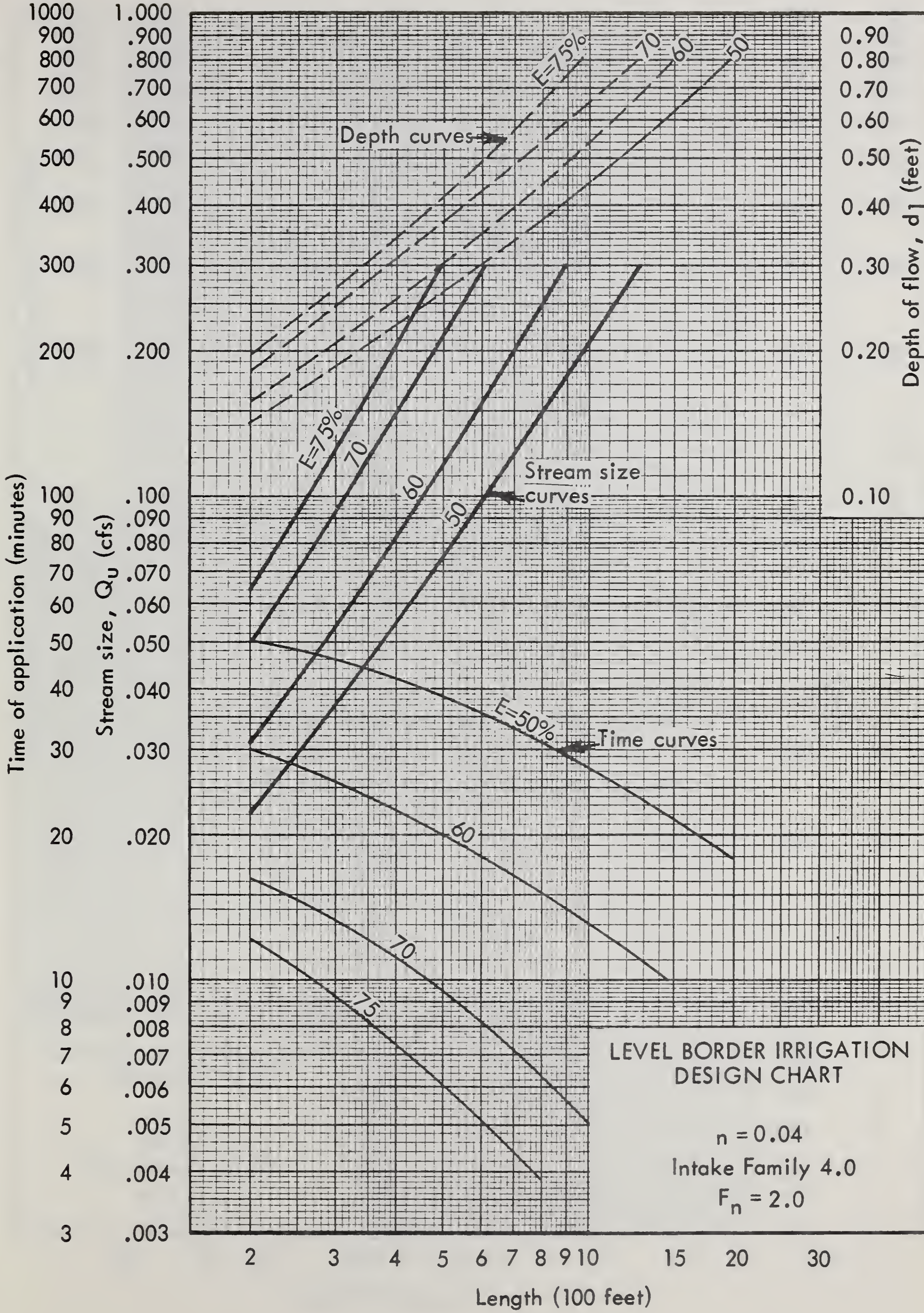
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
2 3 4 5 6 7 8 9 10 15 20 30
Depth curves
E=80% 75 70 60 50
Stream size curves
E=80% 75 70 60 50
E=50% 60 70 75 80
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 3.0

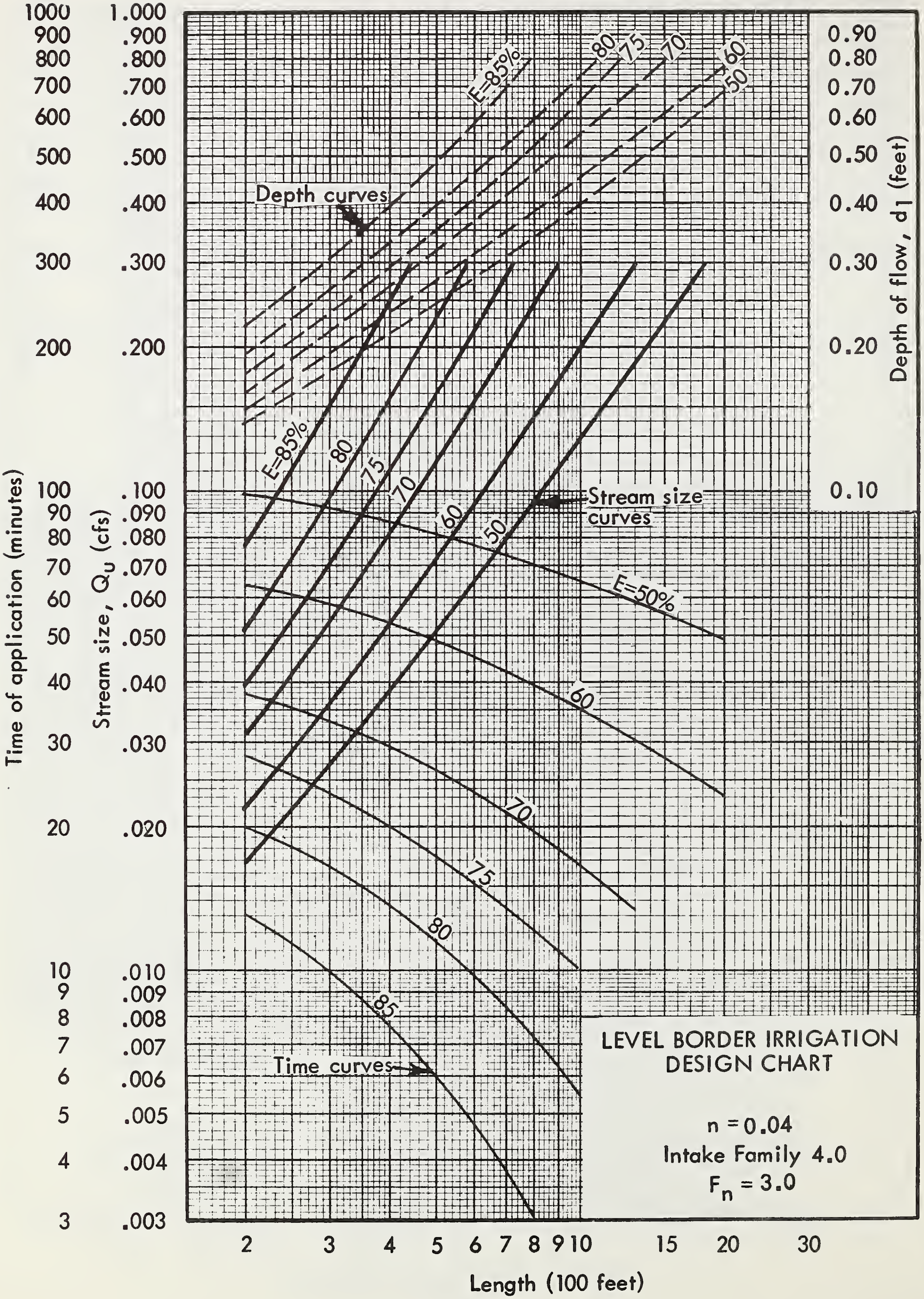


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
2 3 4 5 6 7 8 9 10 15 20 30
Depth curves
E=85% 80 75 70 60 50
E=85% 80 75 70 60 50
E=50% 60 70 75 80 85
Stream size curves
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 4.0

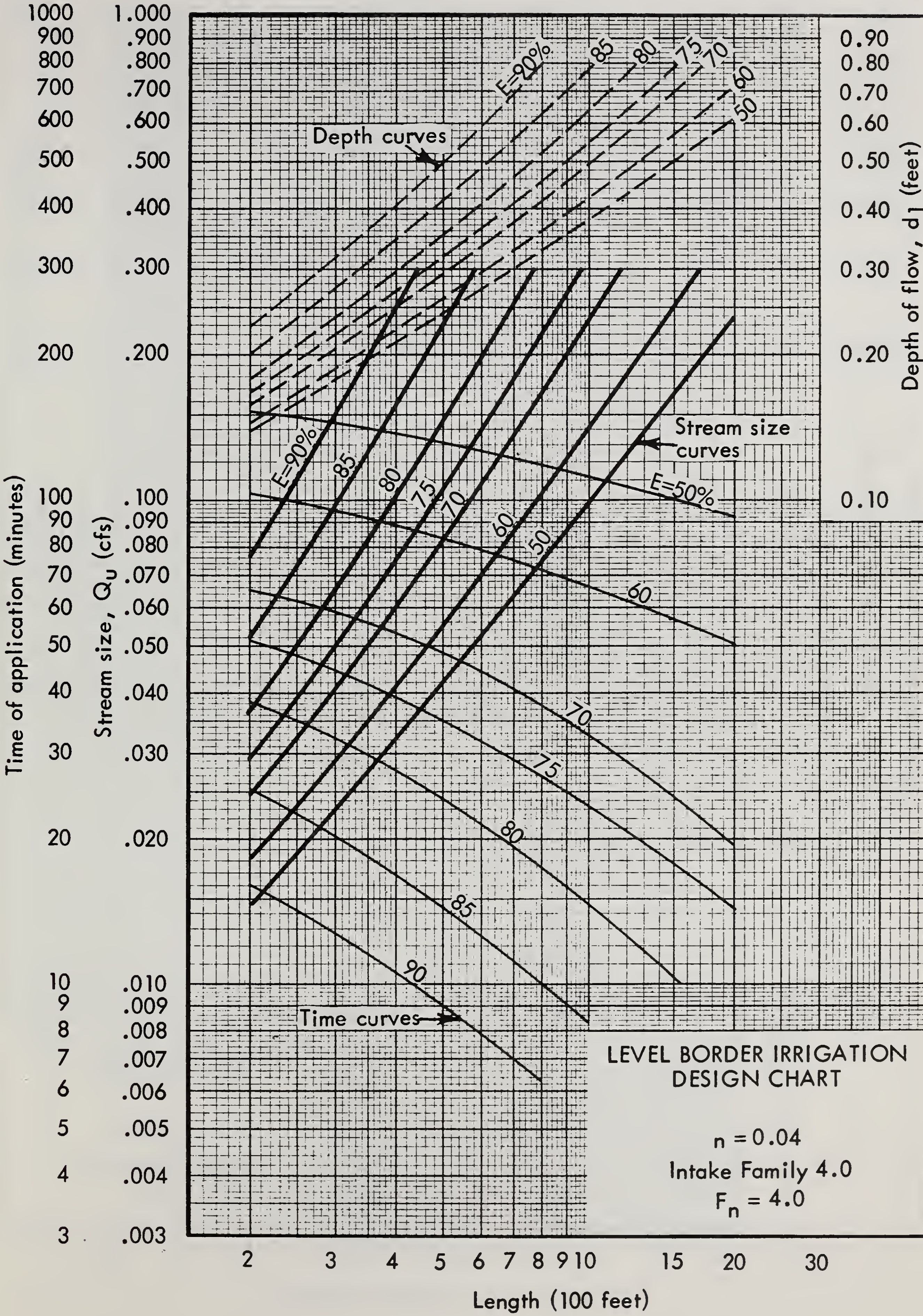


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=90%
85
80
75
70
60
50
E=50%
90
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 3.0
F_n = 5.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=75%
70
60
50
E=50%
75



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 3.0



Time of application (minutes)
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100
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Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
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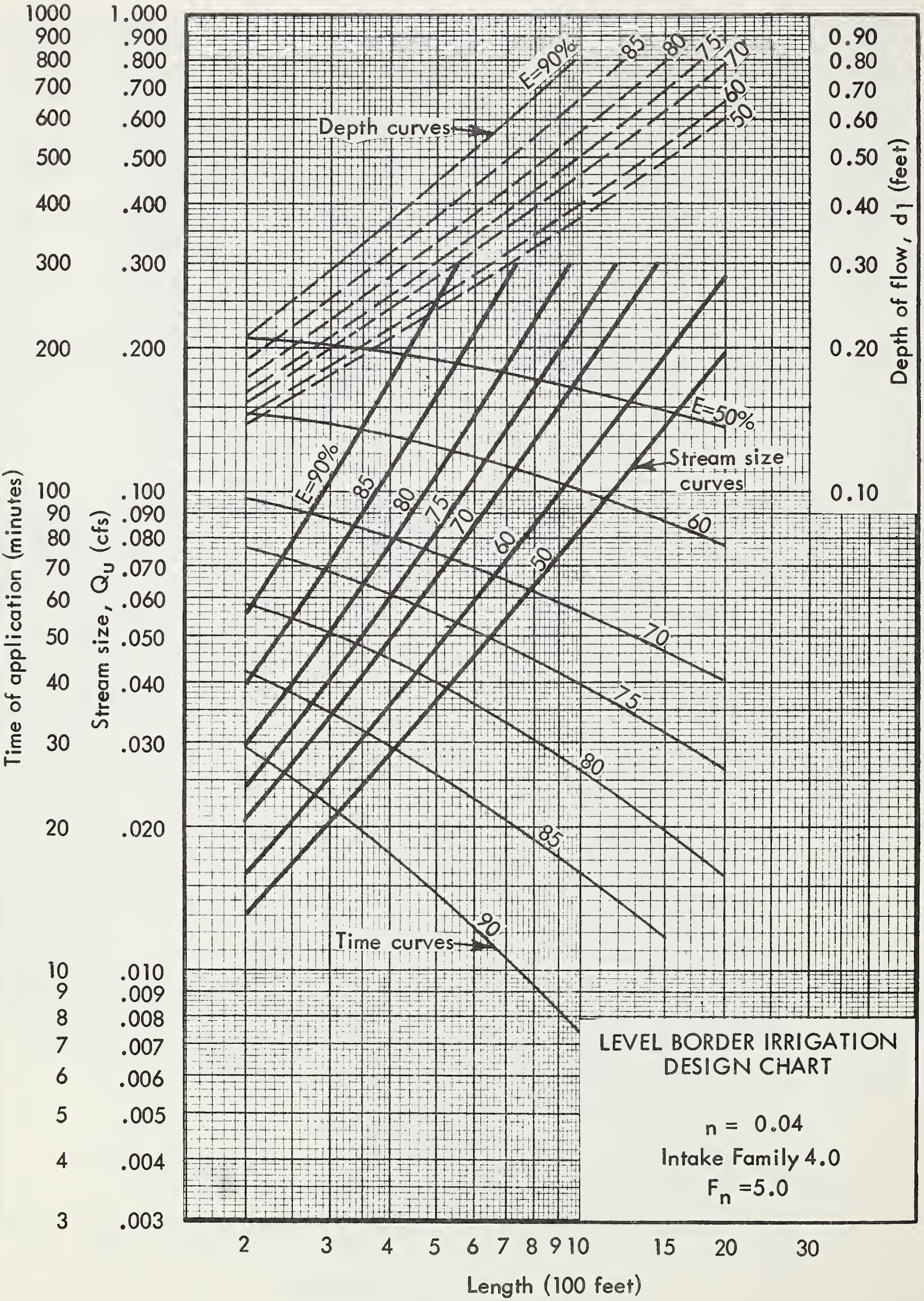
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
E=90%
85
80
75
70
60
50
Stream size curves
E=90%
85
80
75
70
60
50
E=50%
60
70
75
80
85
90
Time curves
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 4.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
1000
900
800
700
600
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1.000
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.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
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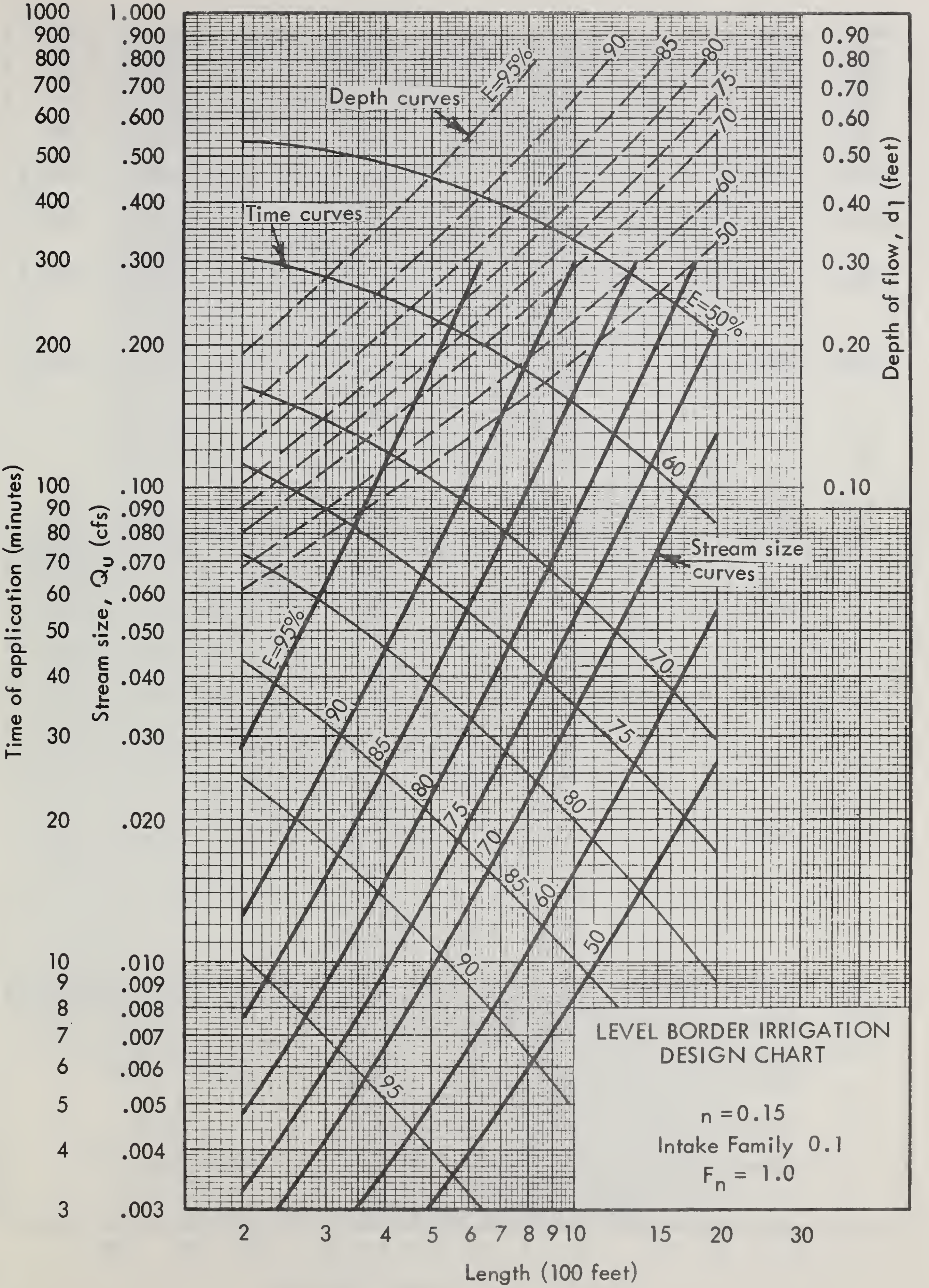
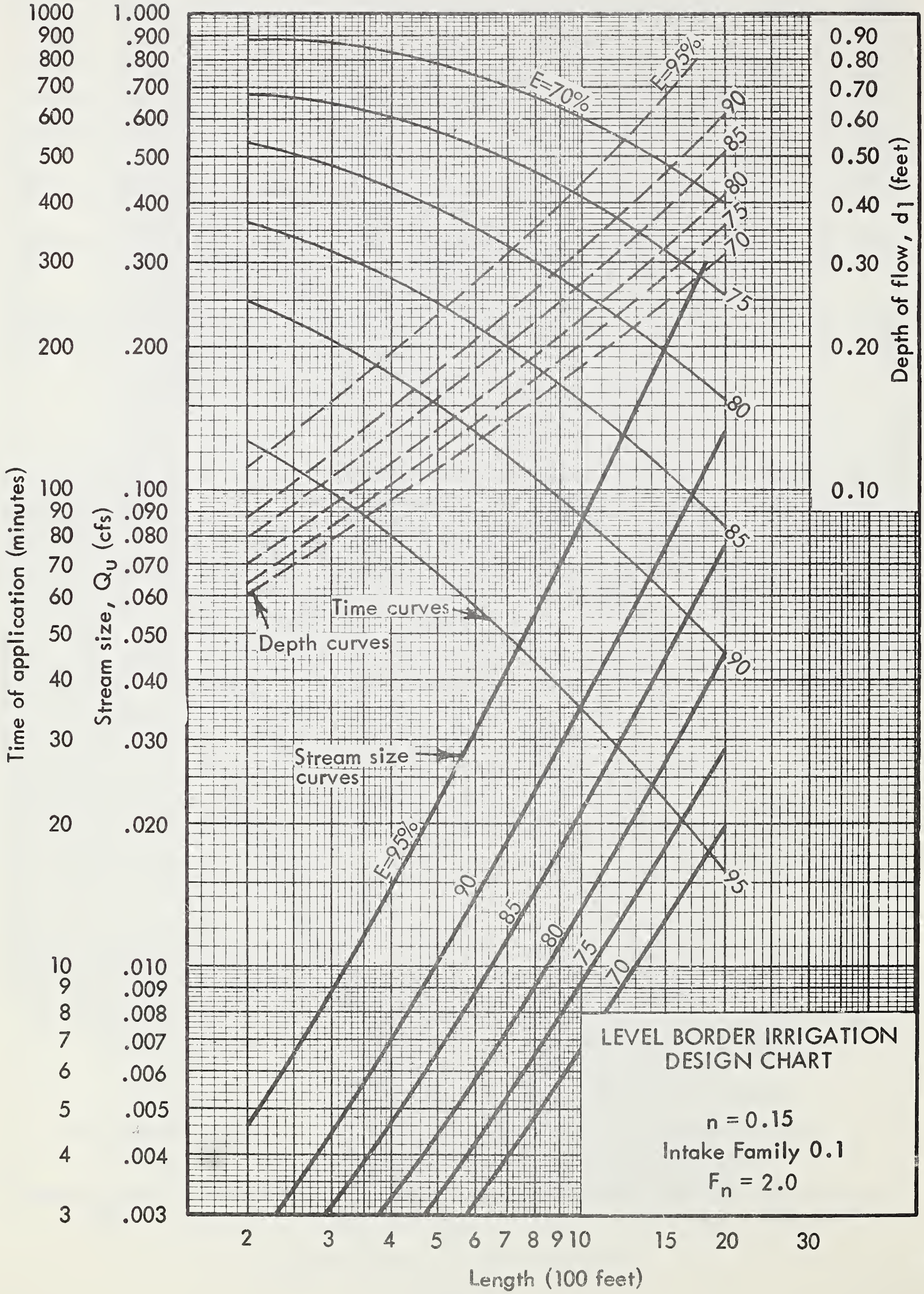
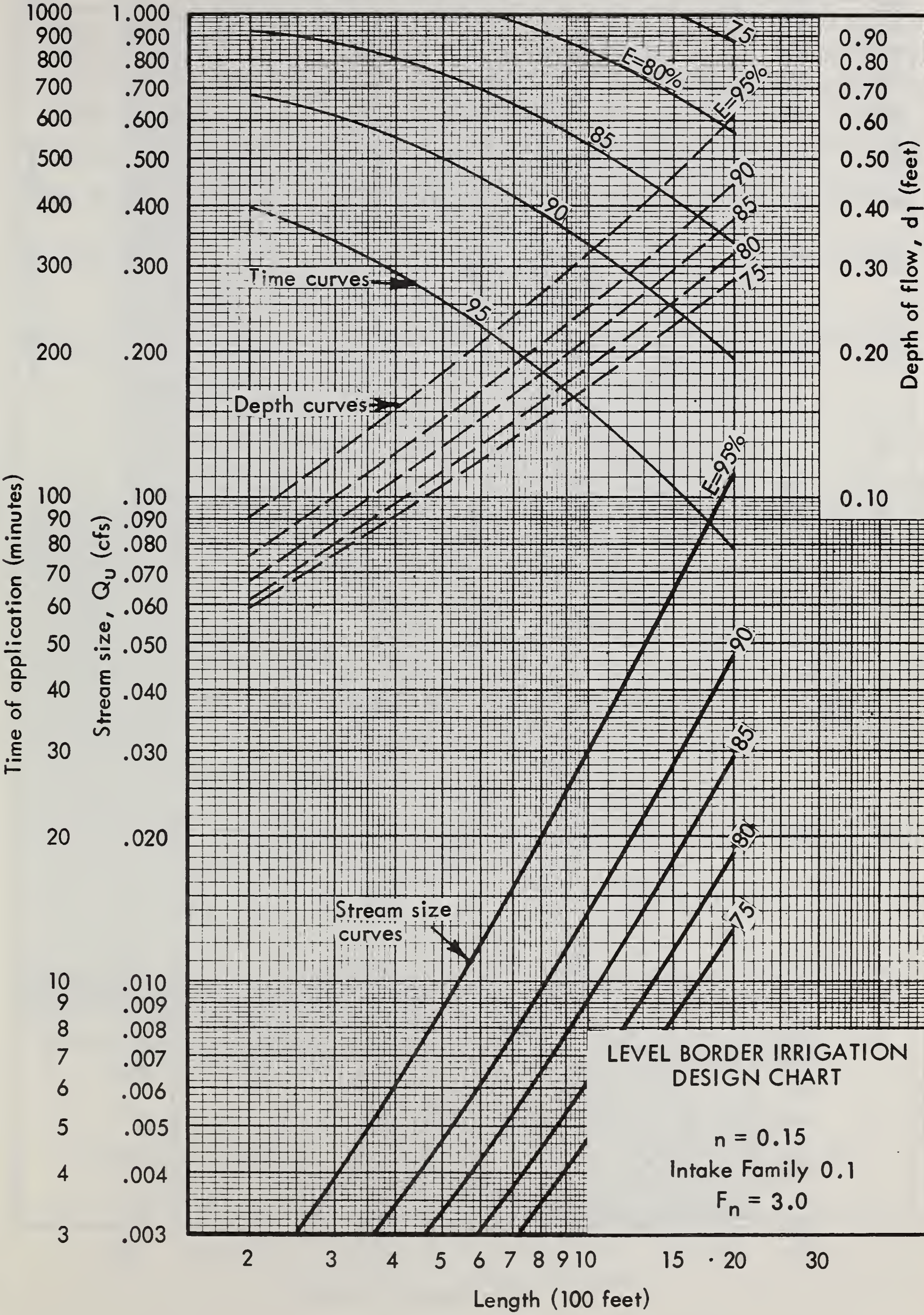
6
7
8
9
10
15
20
30
Depth curves
E=90%
85
80
75
70
60
50
Stream size curves
E=90%
85
80
75
70
60
50
E=50%
60
70
75
80
85
90
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n =5.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=95%
E=50%
LEVEL BORDER IRRIGATION
DESIGN CHART
n =0.15
Intake Family 0.1
F_n = 1.0


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=70%
E=95%
Time curves
Depth curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.1
F_n = 2.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.1
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=80%
E=95%
75
85
90
95
80
1000
900
800
700
600
500
400
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200
100
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0.90
0.80
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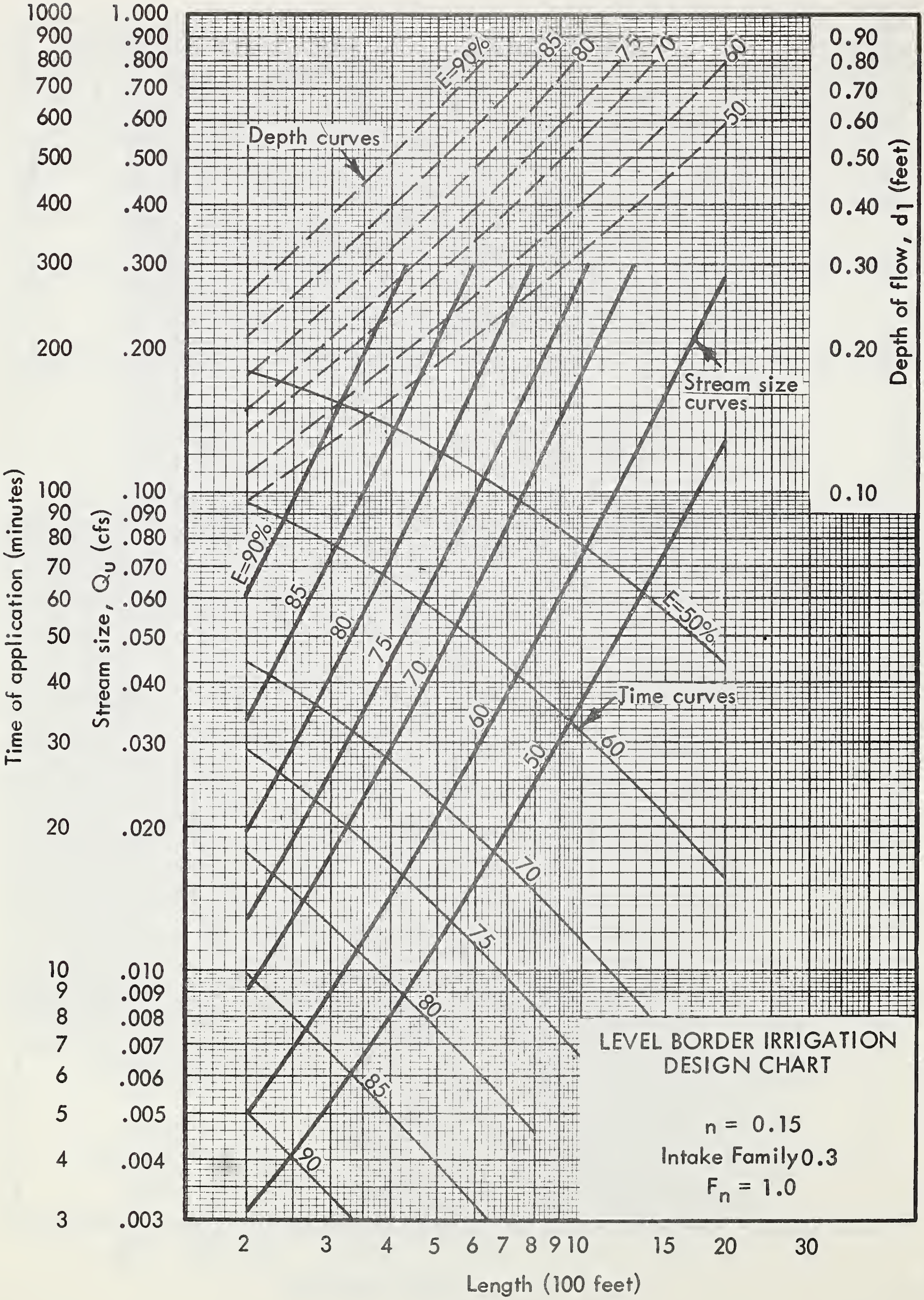
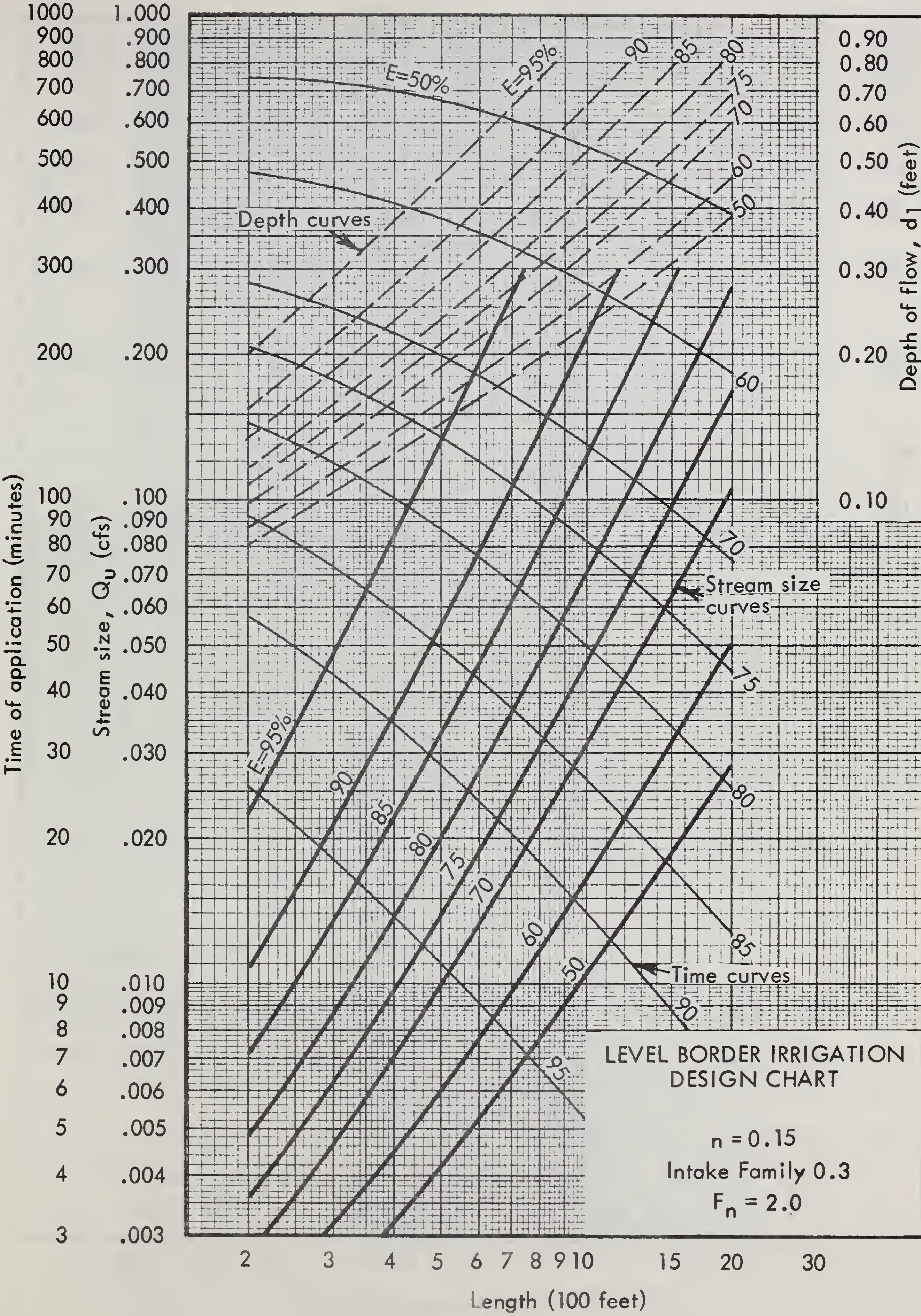

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
E=50%
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 1.0



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=50%
E=95%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
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0.90
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0.70
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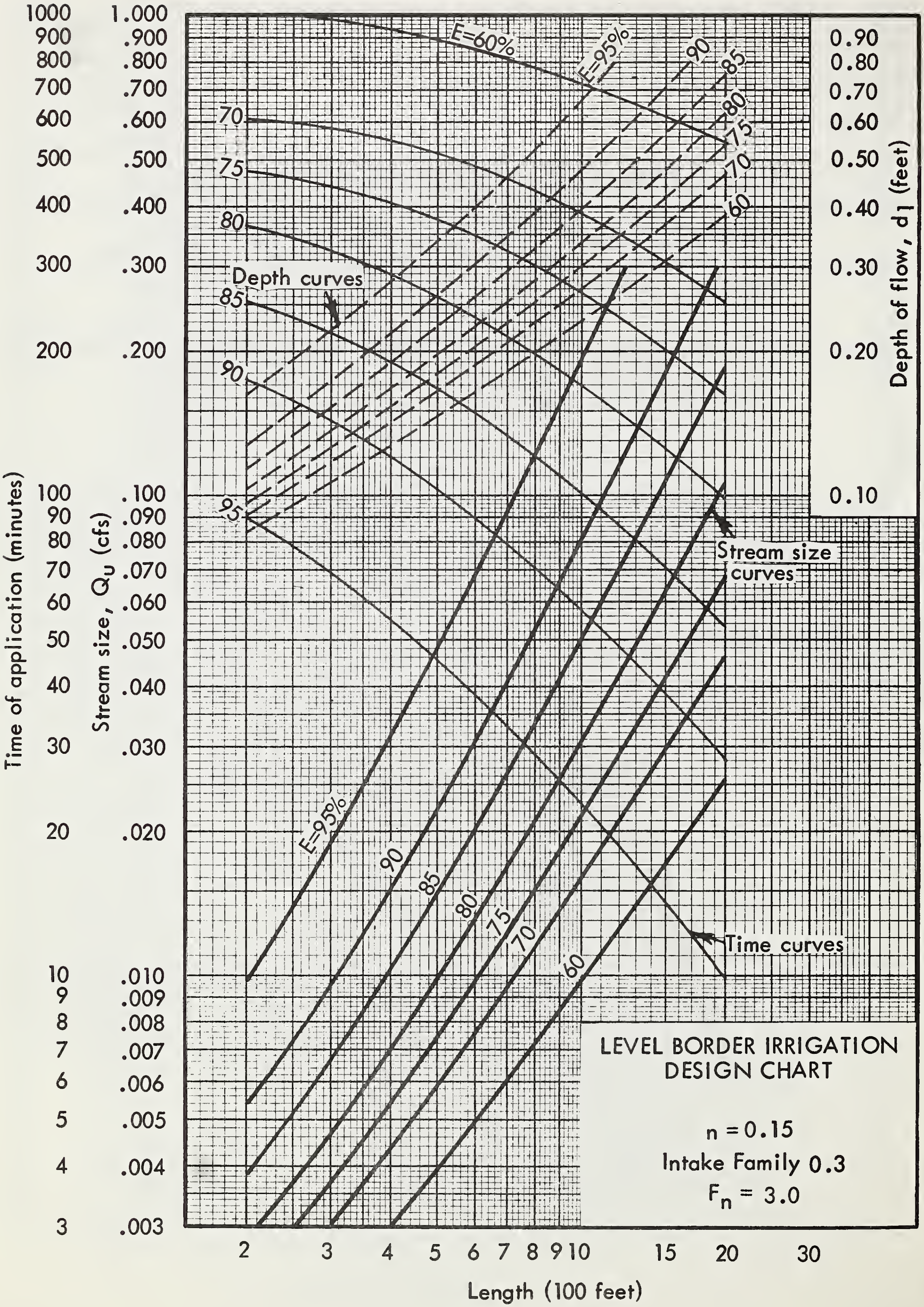
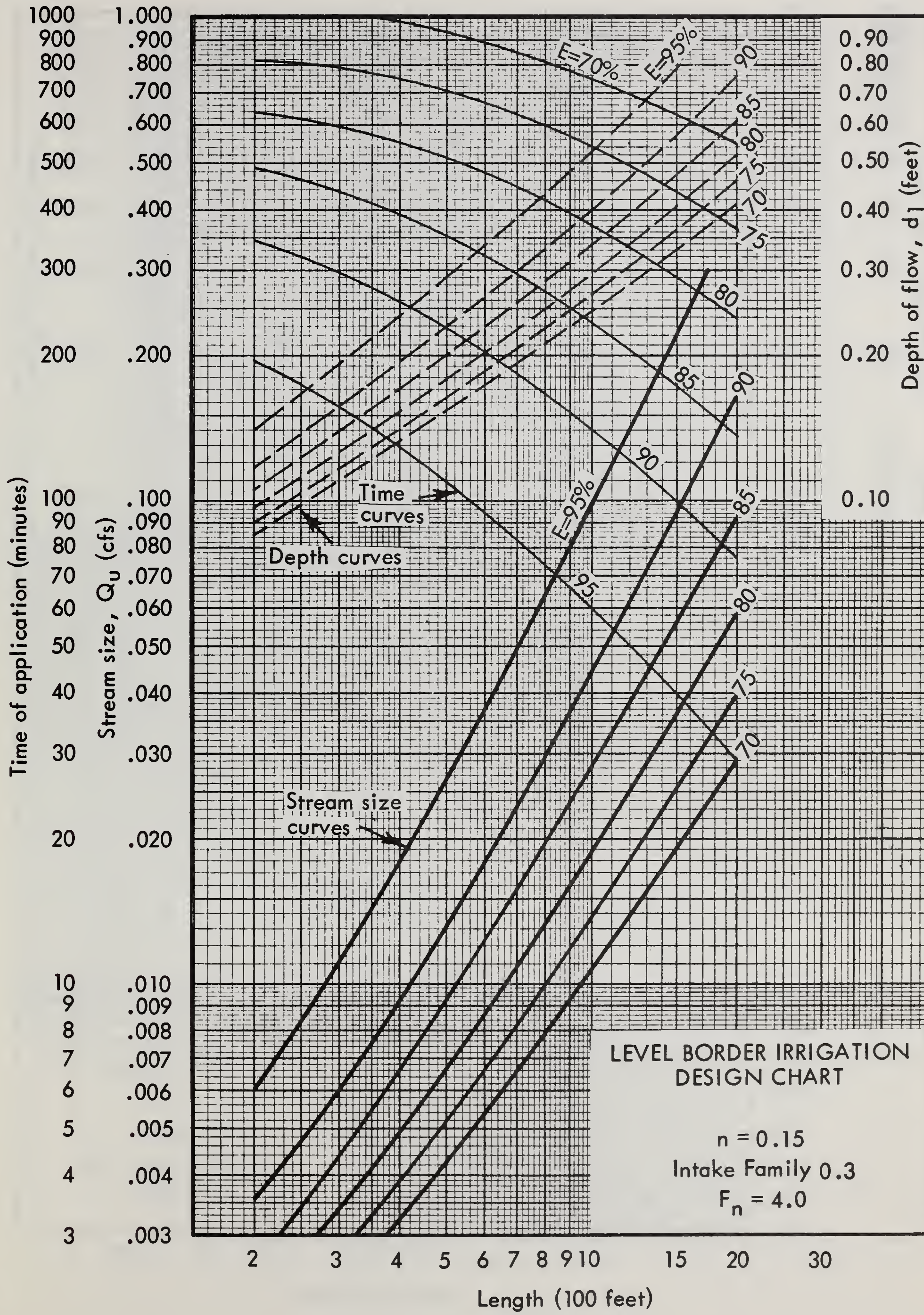
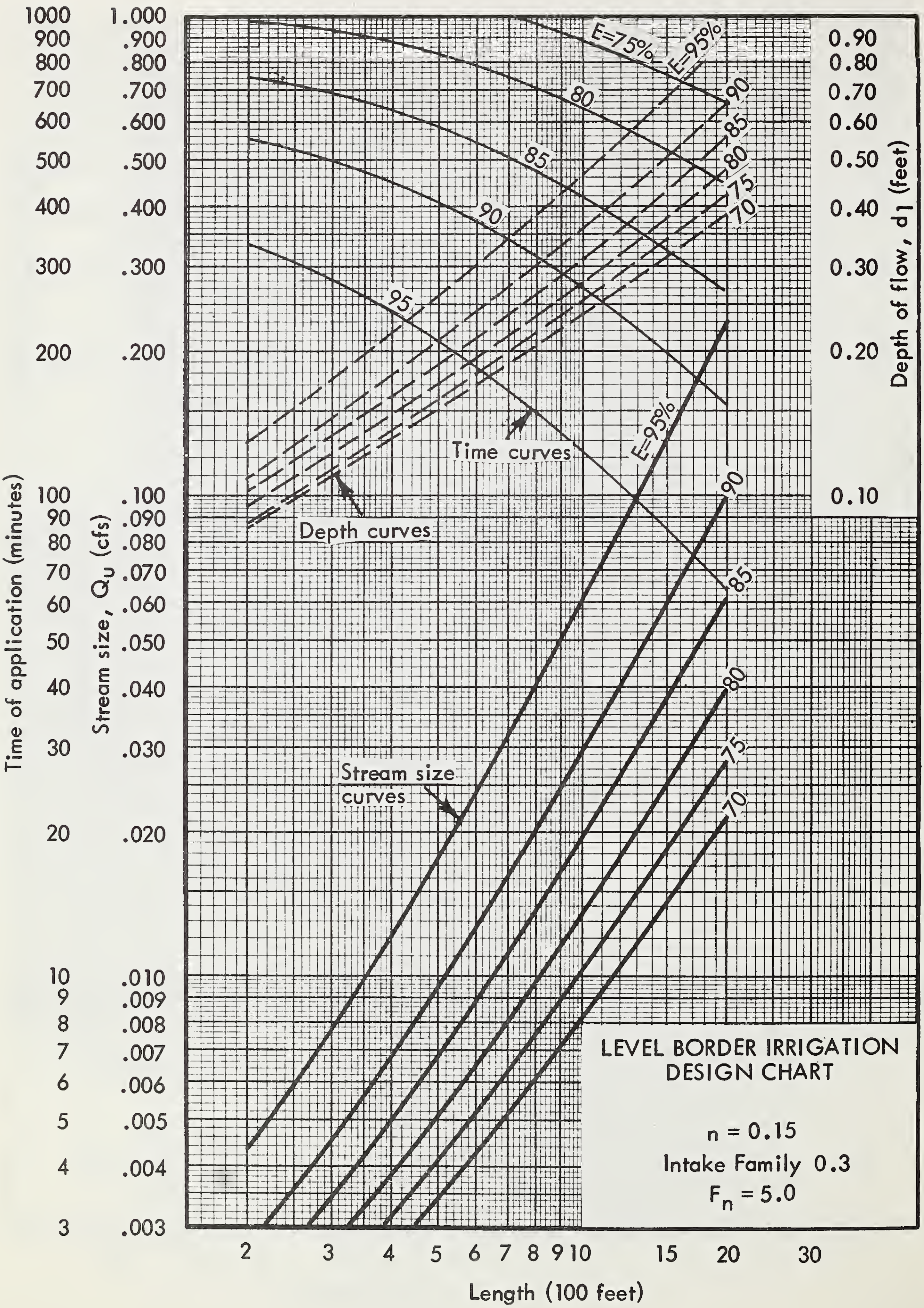


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=60%
E=95%



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=70%
E=95%
Time curves
Depth curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 4.0



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=75%
E=95%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
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9
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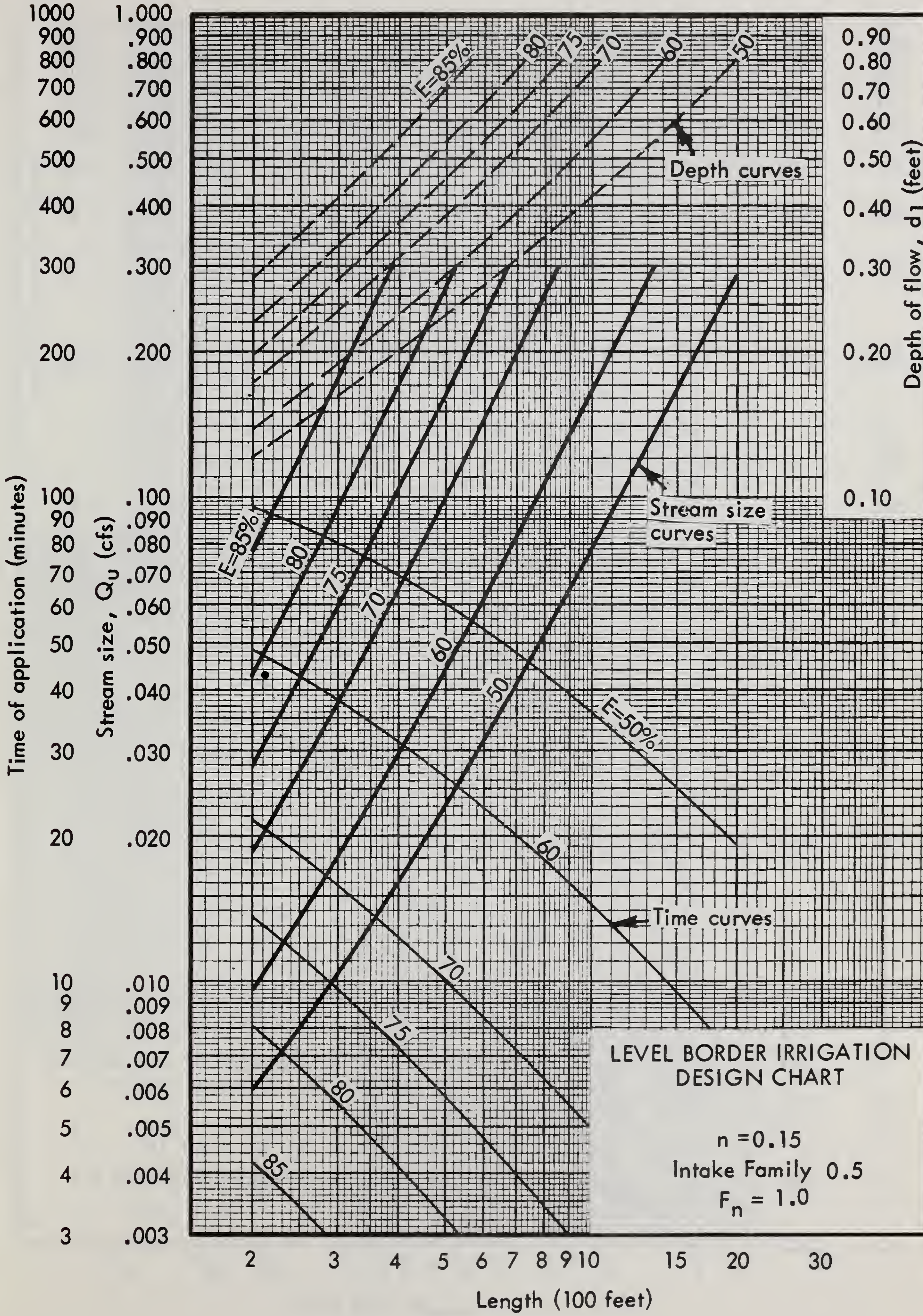
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 0.5
F_n = 1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85
1000
900
800
700
600
500
400
300
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100
90
80
70
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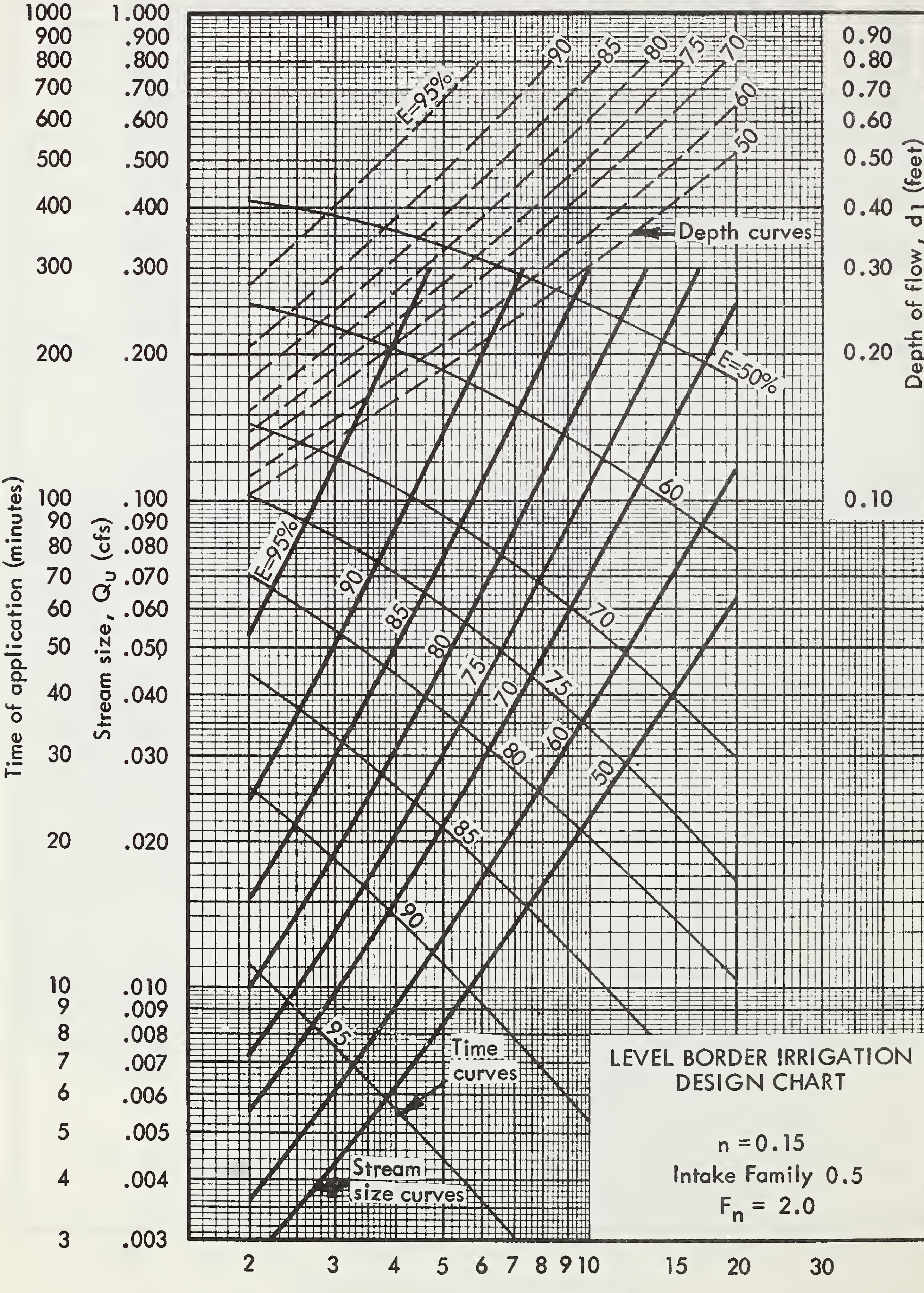
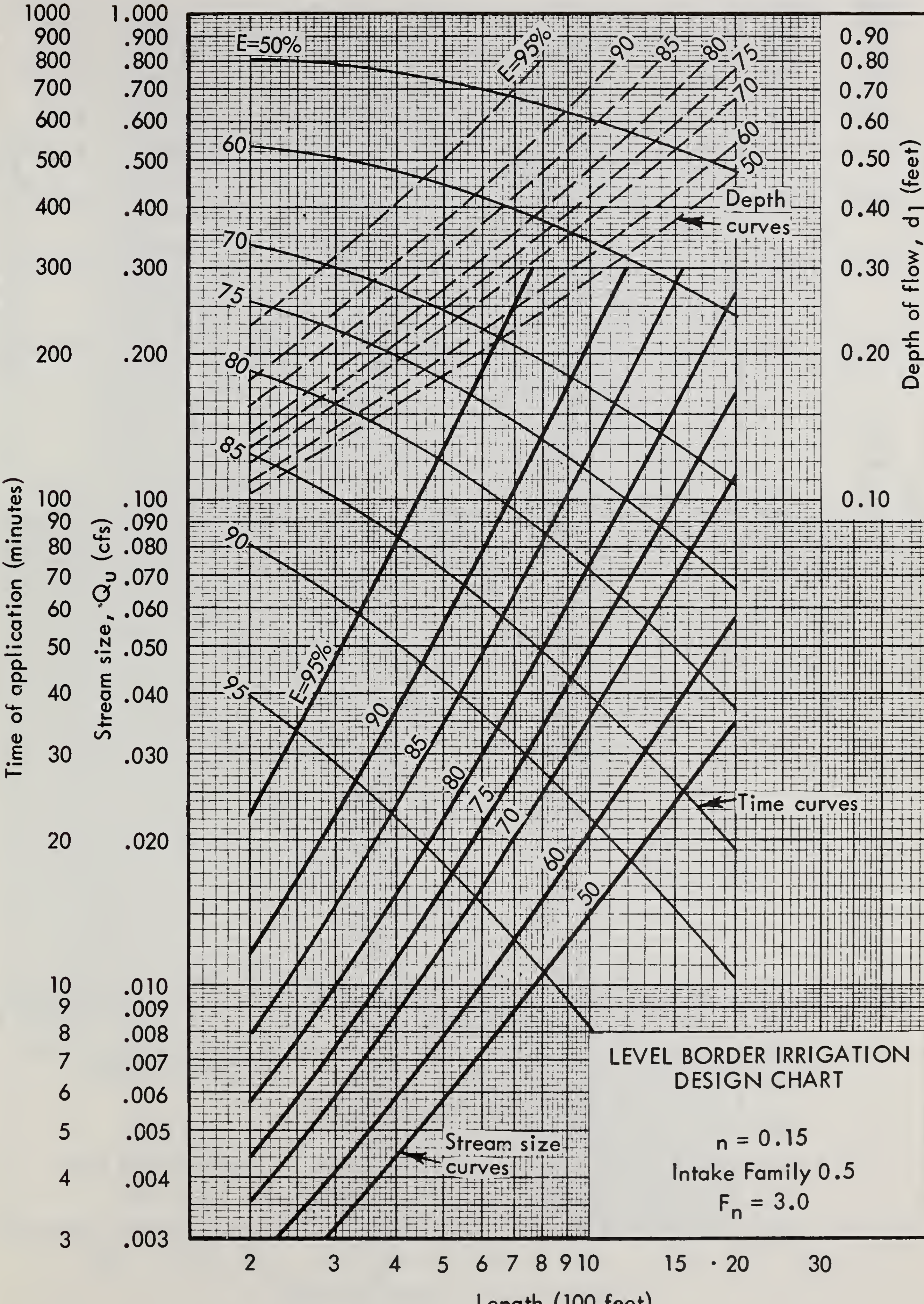
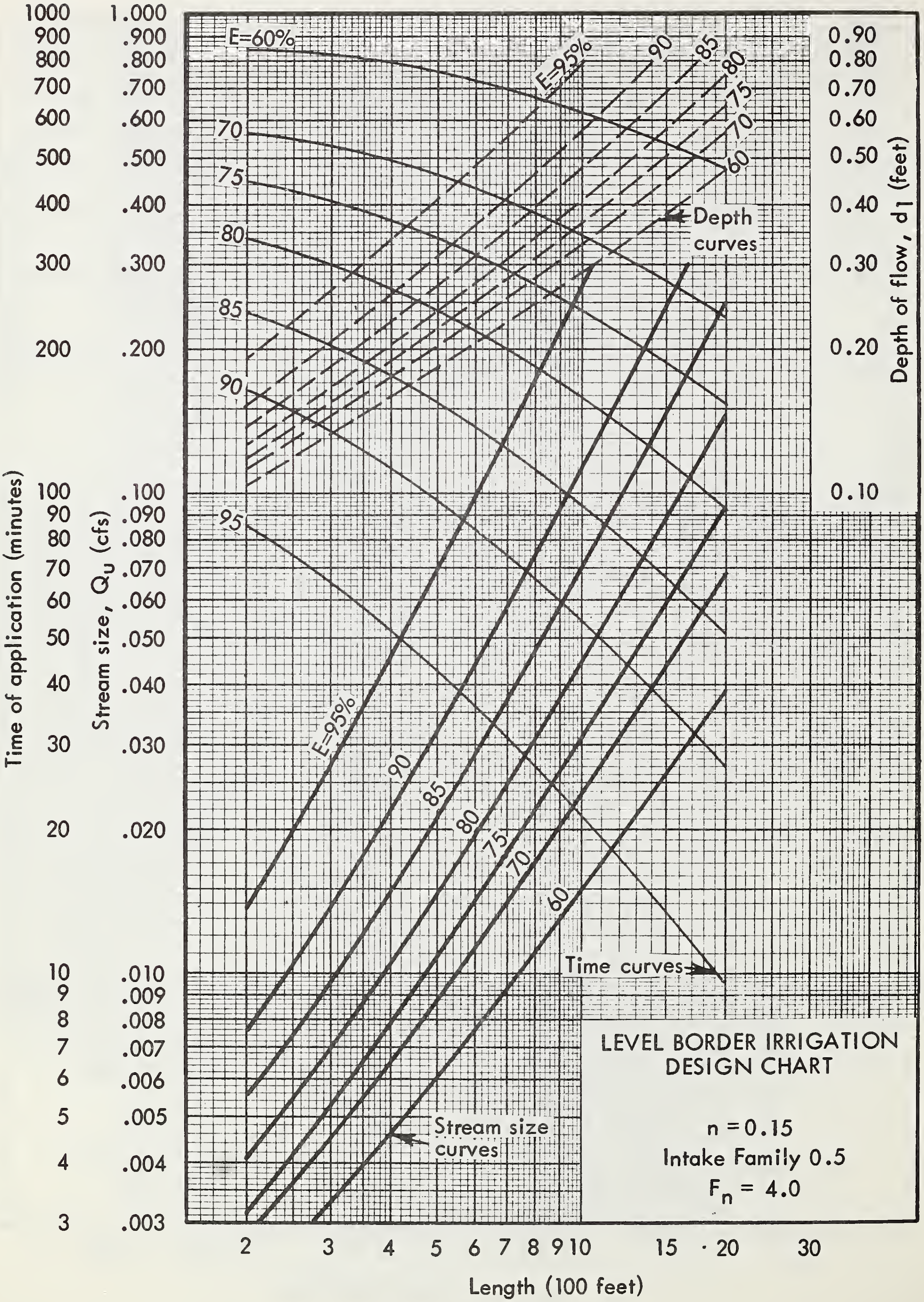


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
2 3 4 5 6 7 8 9 10 15 20 30
E=95% 90 85 80 75 70 60 50
Depth curves
E=50%
Time curves
Stream size curves
LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 2.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=50%
E=95%
Depth curves
Time curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 3.0



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=60%
70
75
80
85
90
95
E=95%
90
85
80
75
70
60
Depth curves
Time curves
Stream size curves
1000
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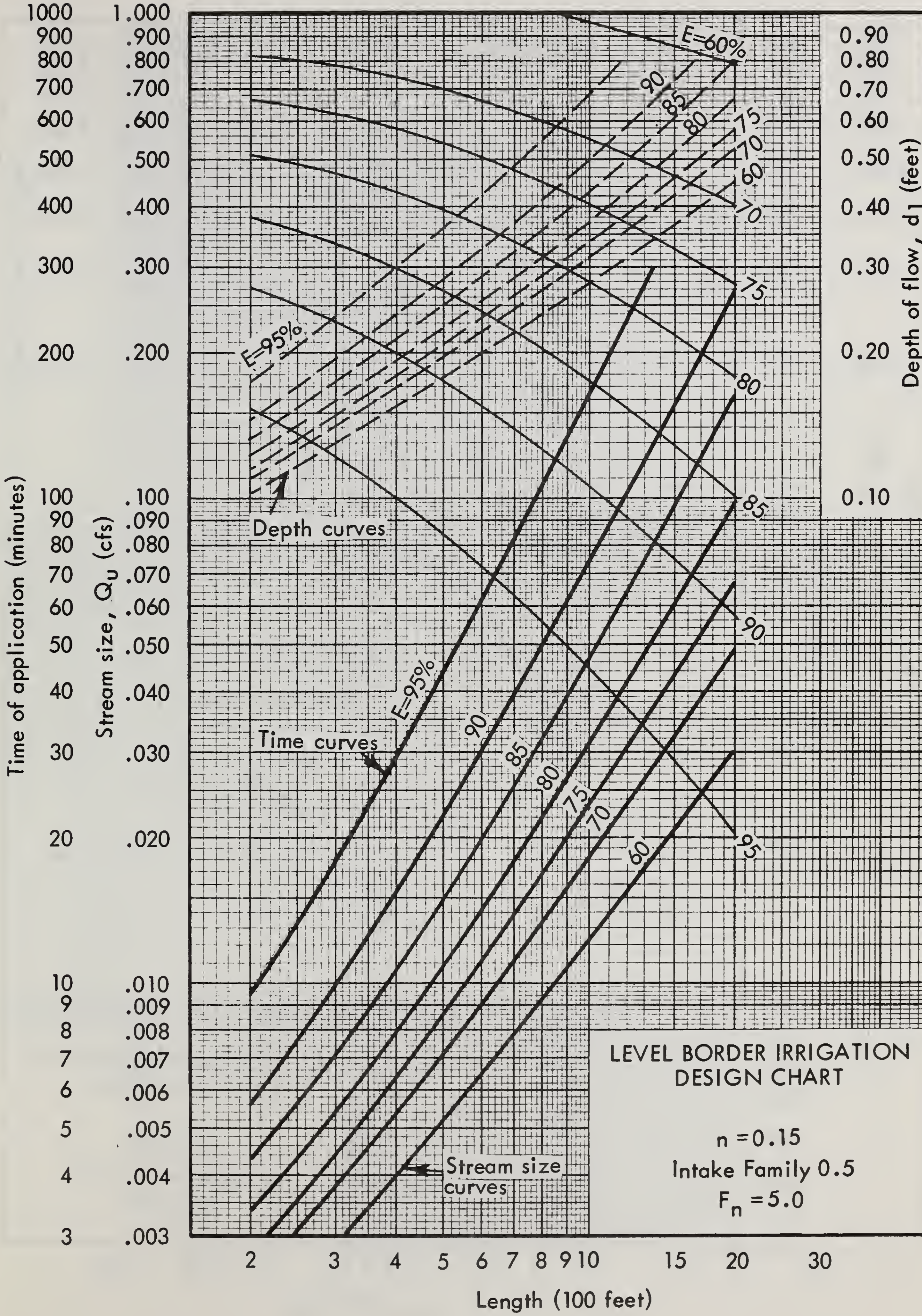
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=60%
E=95%
1000
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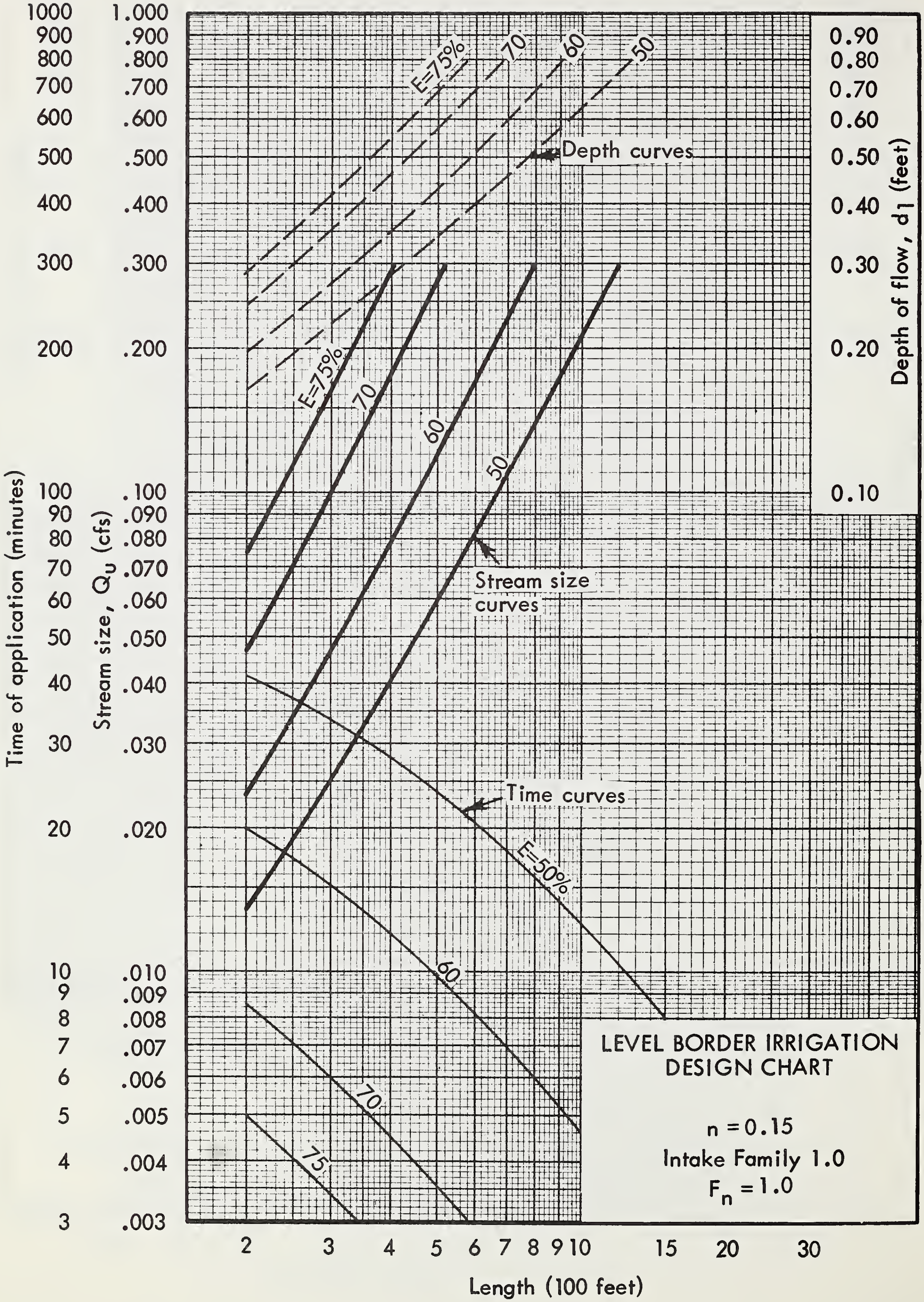
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=75%
70
60
50
E=50%
75
1000
900
800
700
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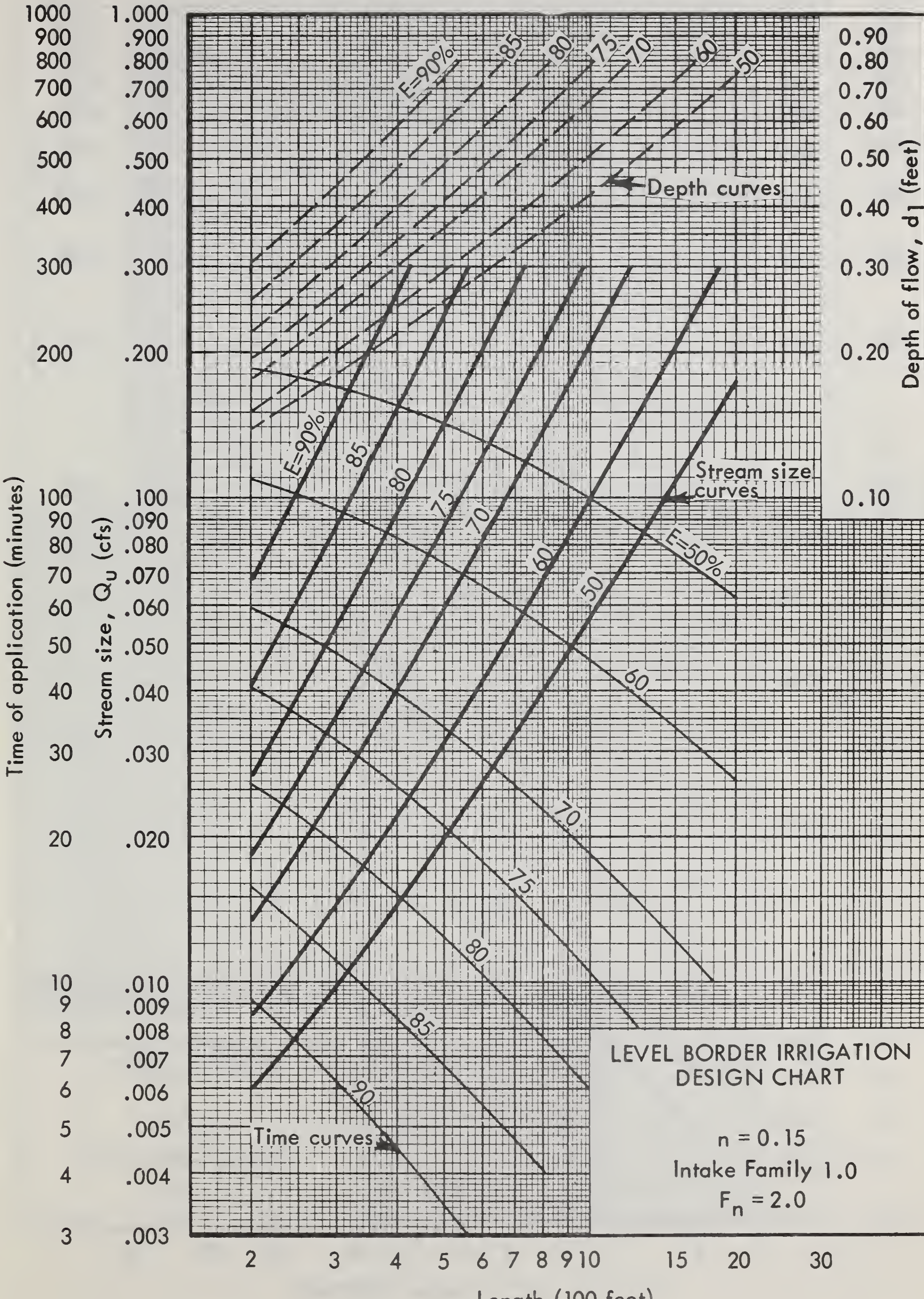
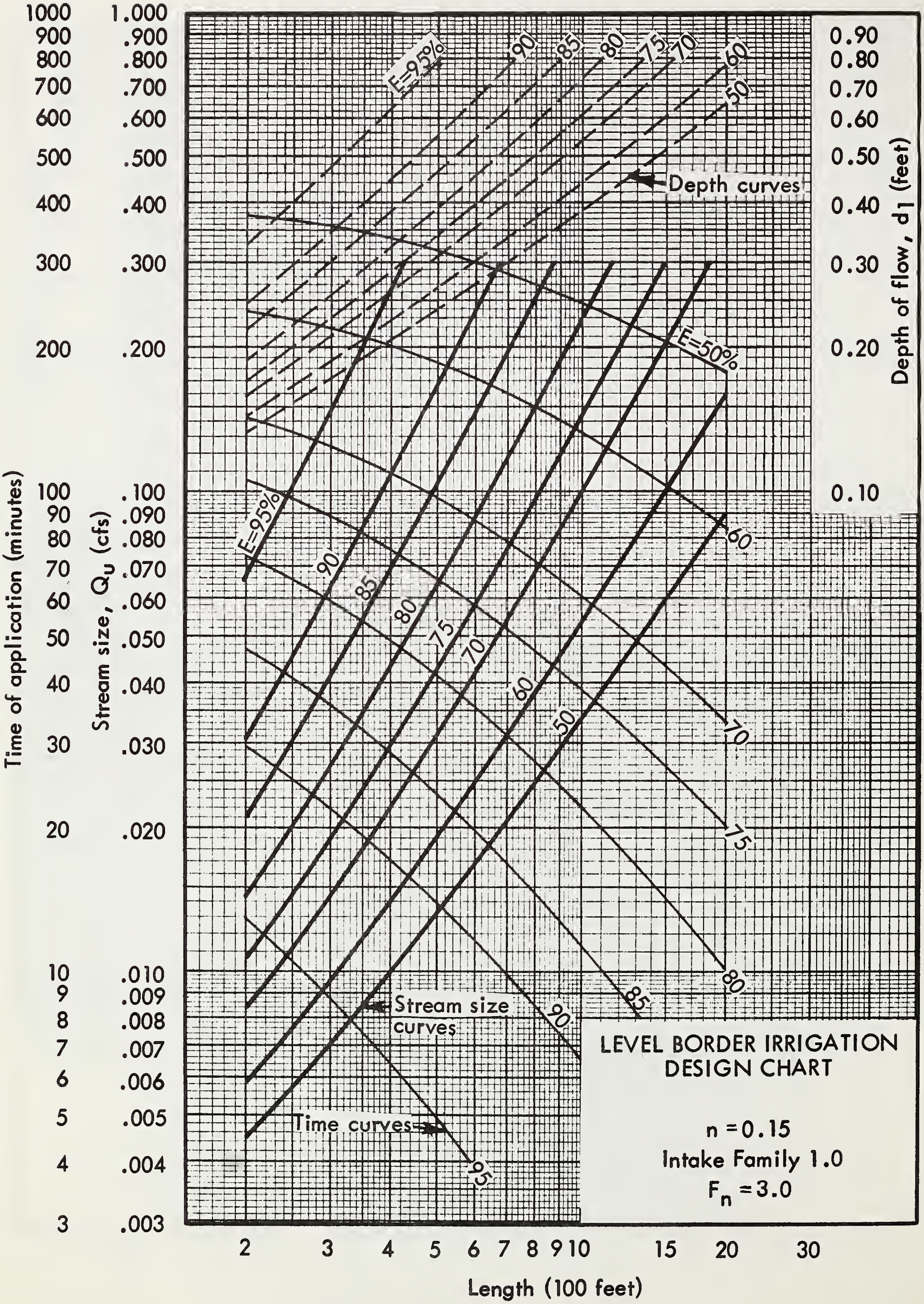
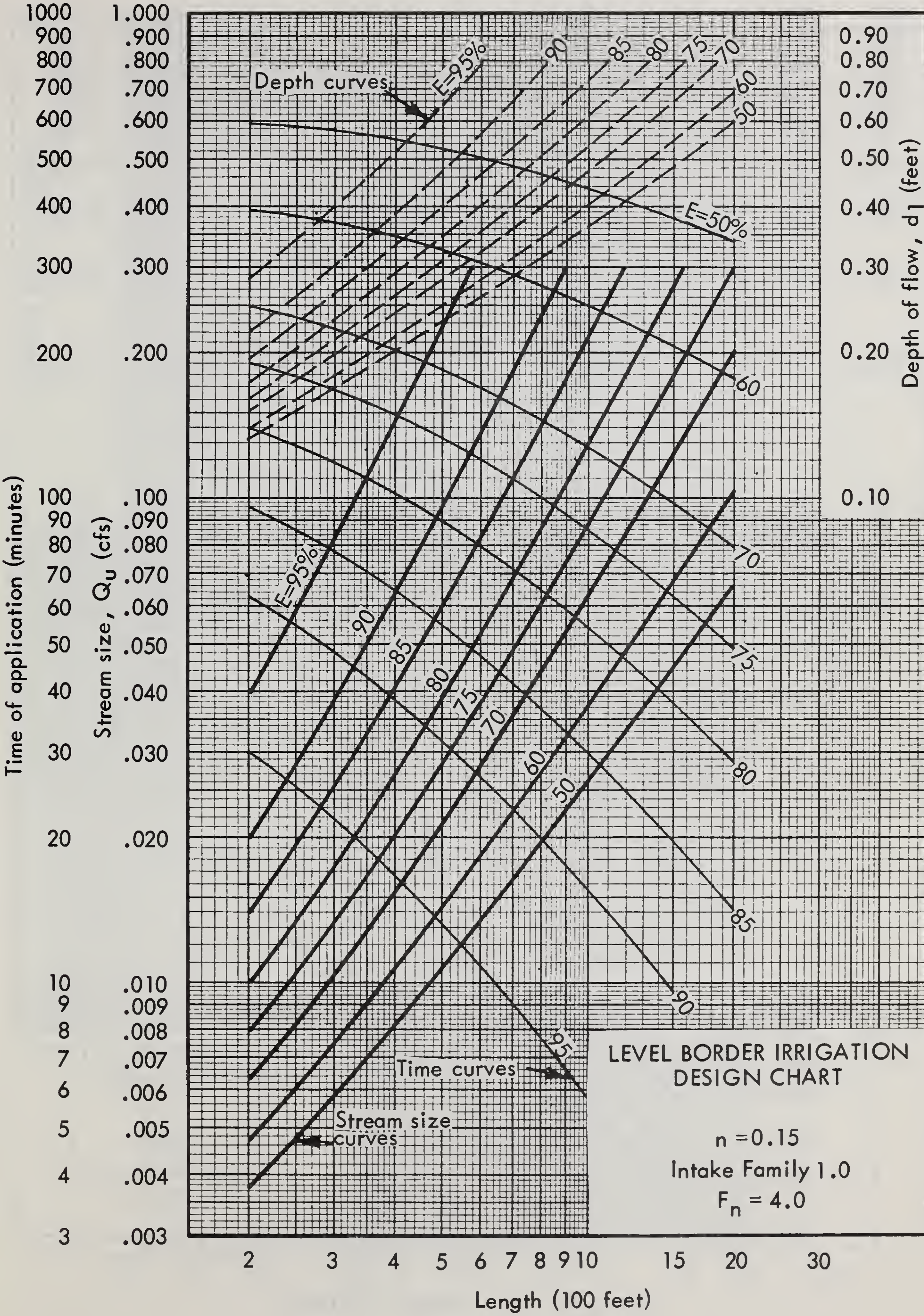

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
85
80
75
70
60
50
E=50%
90
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 2.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=95%
E=50%
E=95%


LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.0
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=95%
E=50%
1000
900
800
700
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500
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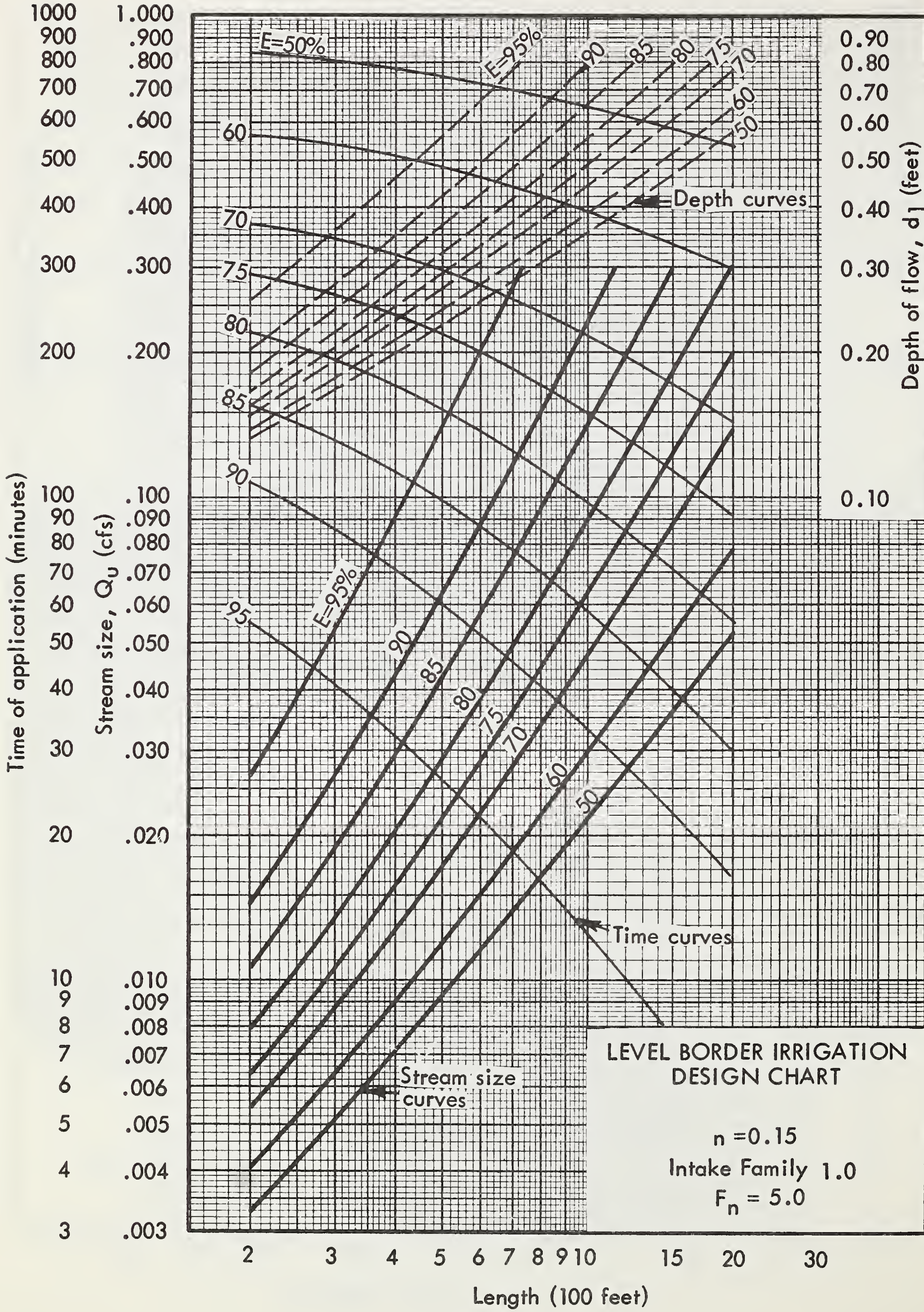
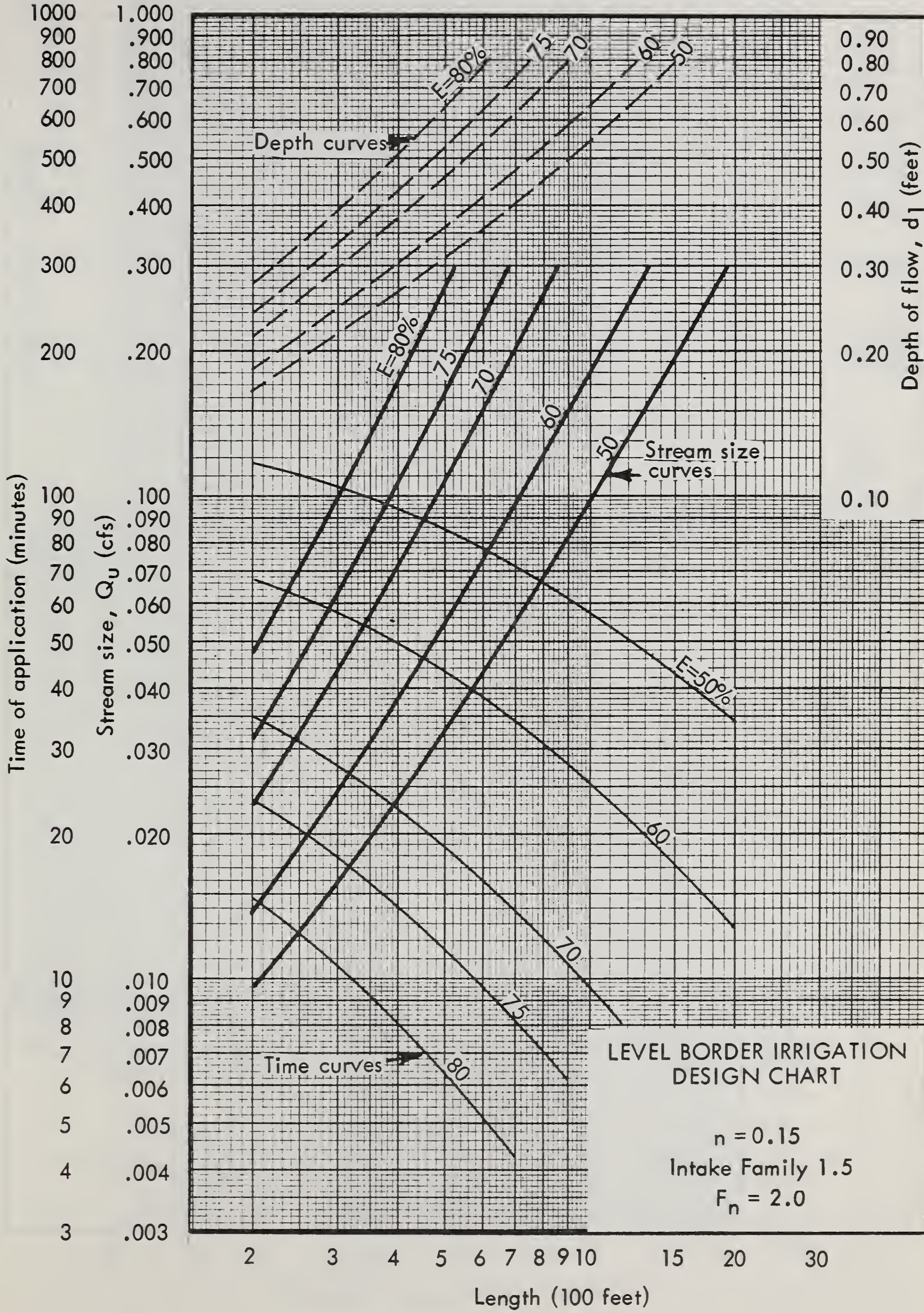


LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.0
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=50%
E=95%
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
2 3 4 5 6 7 8 9 10 15 20 30



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
80
1000
900
800
700
600
500
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0.90
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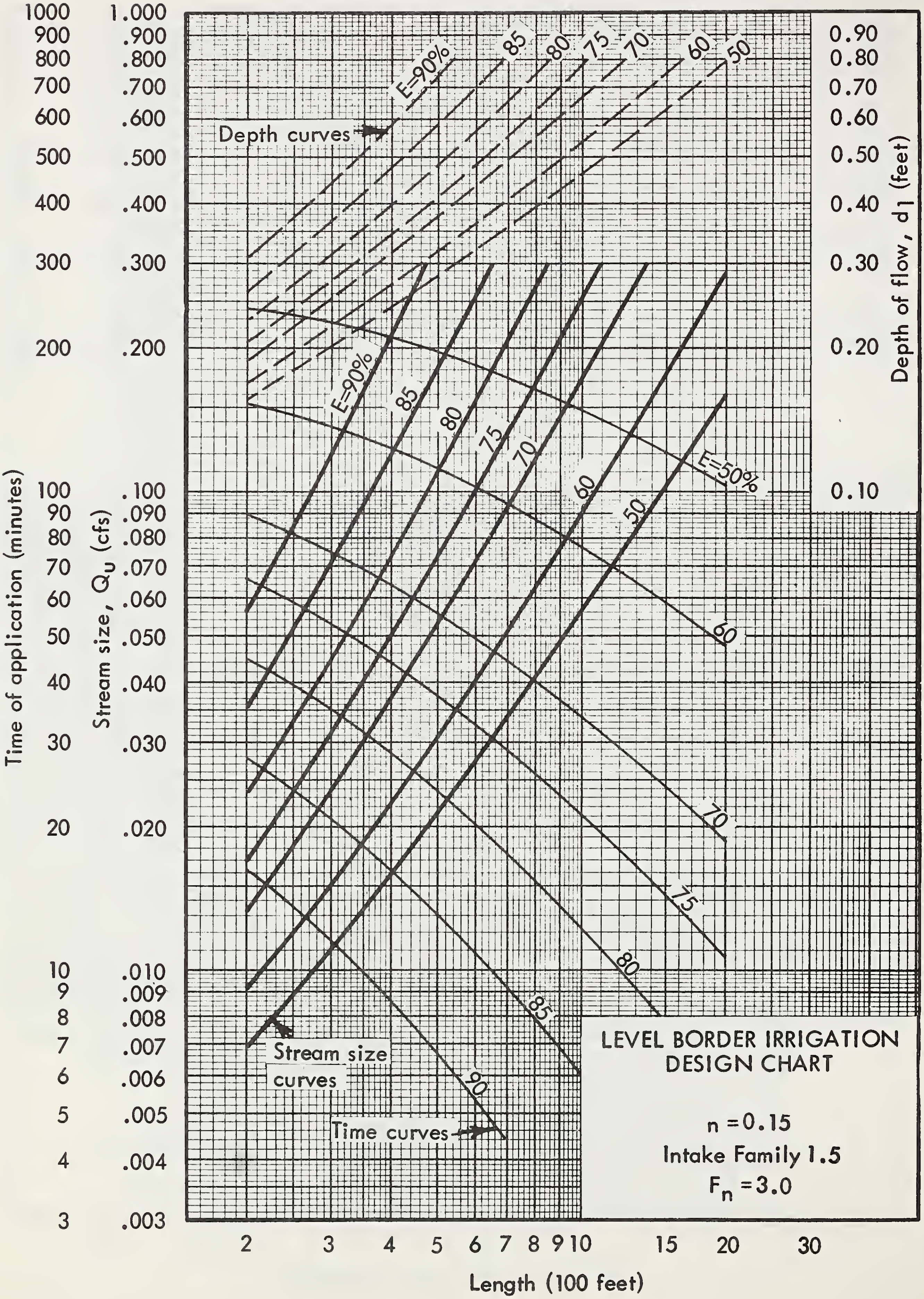
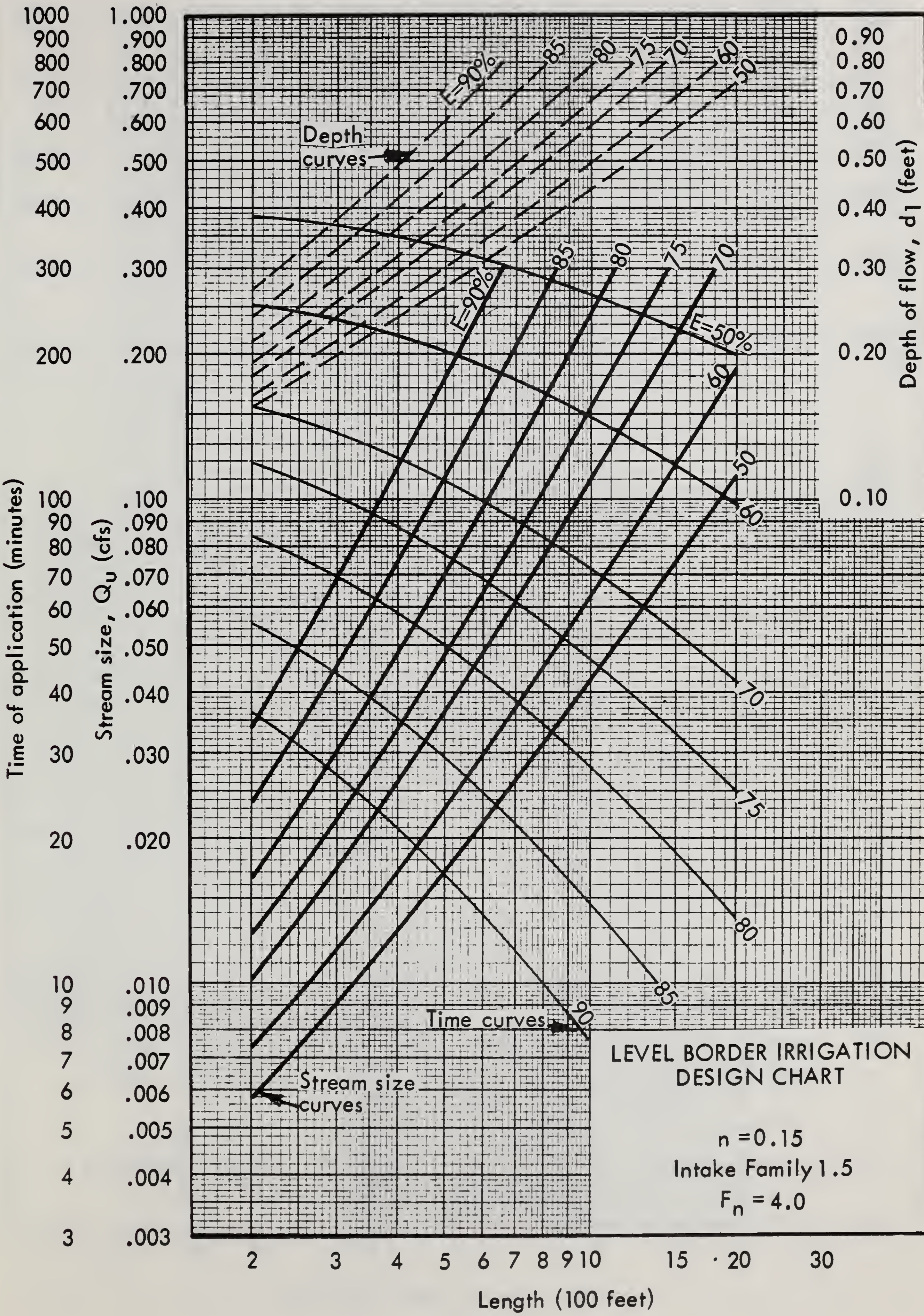

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
85
80
75
70
60
50
E=50%
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.5
F_n =3.0


LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.5
F$_n$ = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=90%
85
80
75
70
60
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E=50%
1000
900
800
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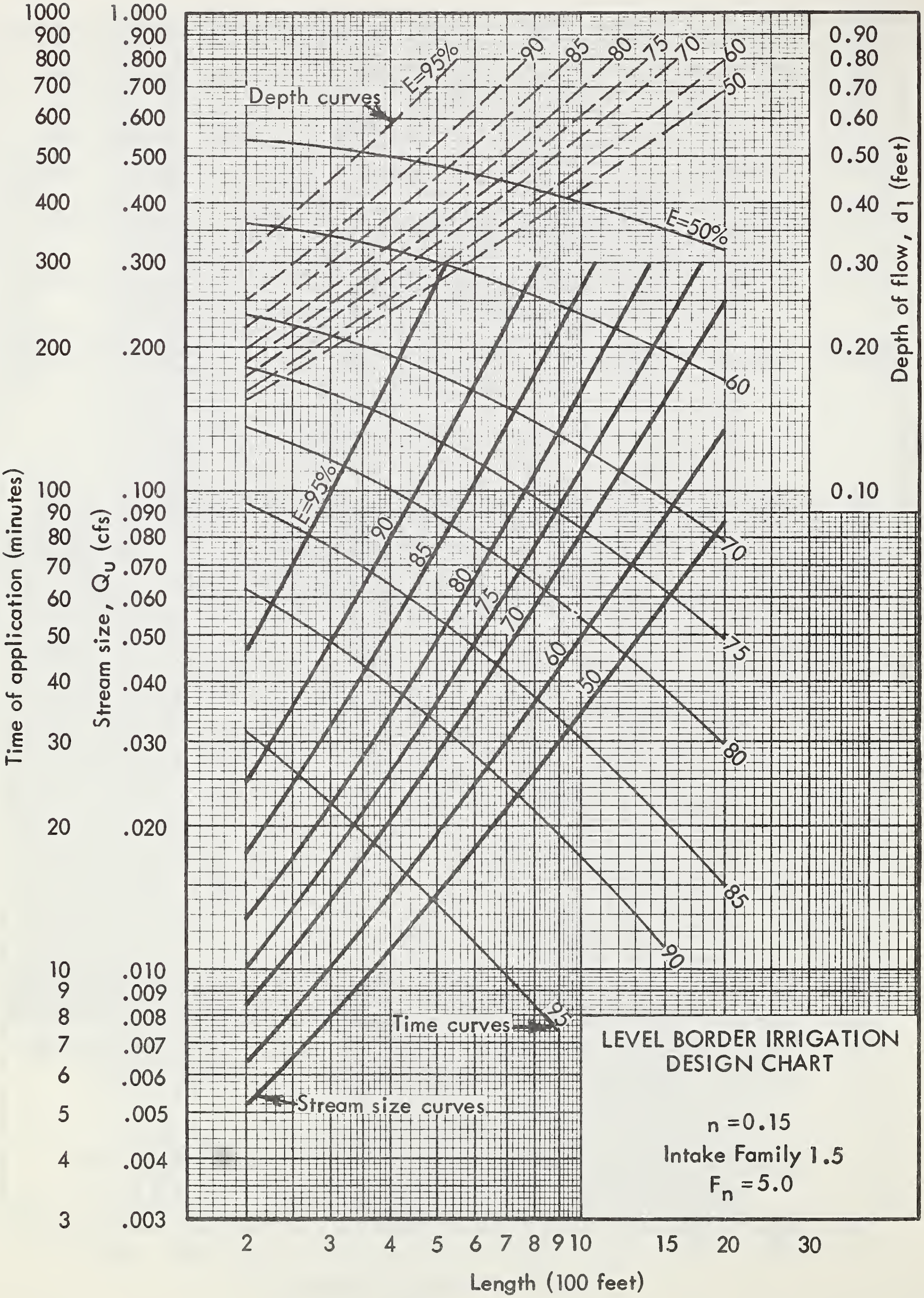
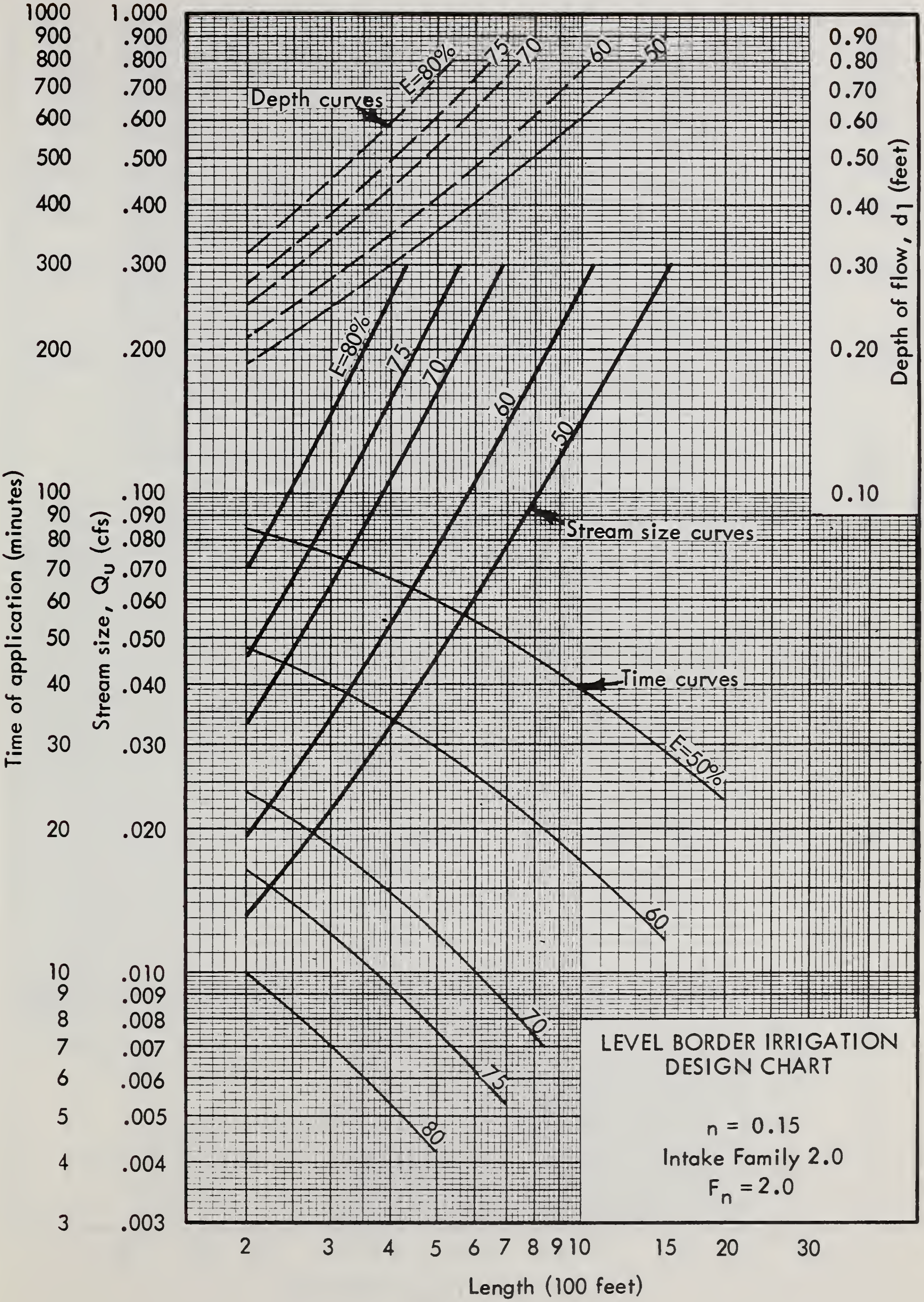

LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.5
F_n =5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=95%
E=50%



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F n = 2.0
Depth curves
E=80%
75
70
60
50
Stream size curves
Time curves
E=50%
80
Time of application (minutes)
Stream size, Q u (cfs)
Depth of flow, d 1 (feet)
Length (100 feet)
1000
900
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700
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500
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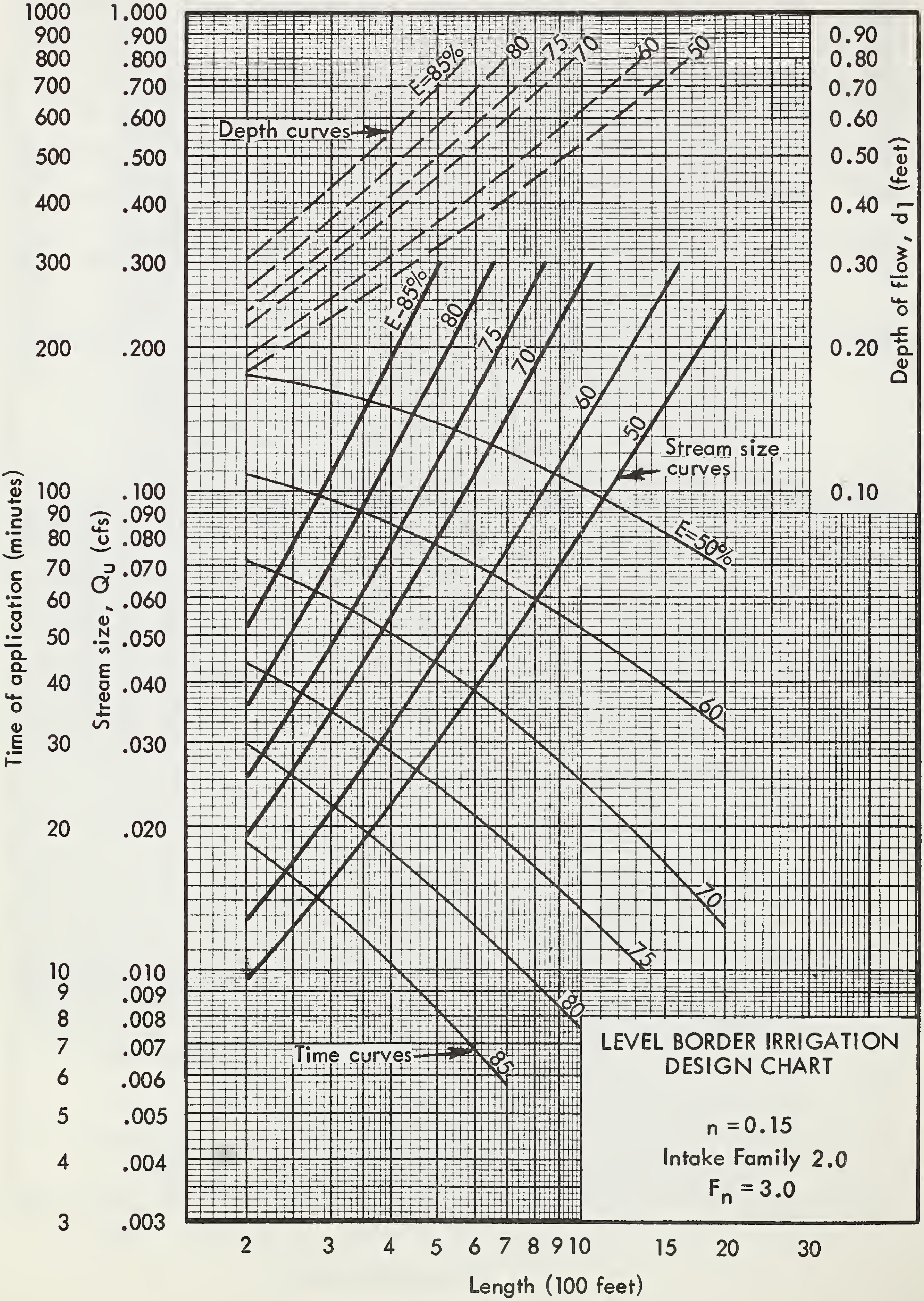

Time of application (minutes)
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900
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Stream size, Q_u (cfs)
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Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
E=85%
80
75
70
60
50
E-85%
80
75
70
60
50
Stream size curves
E=50%
60
70
75
80
85
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 3.0
2
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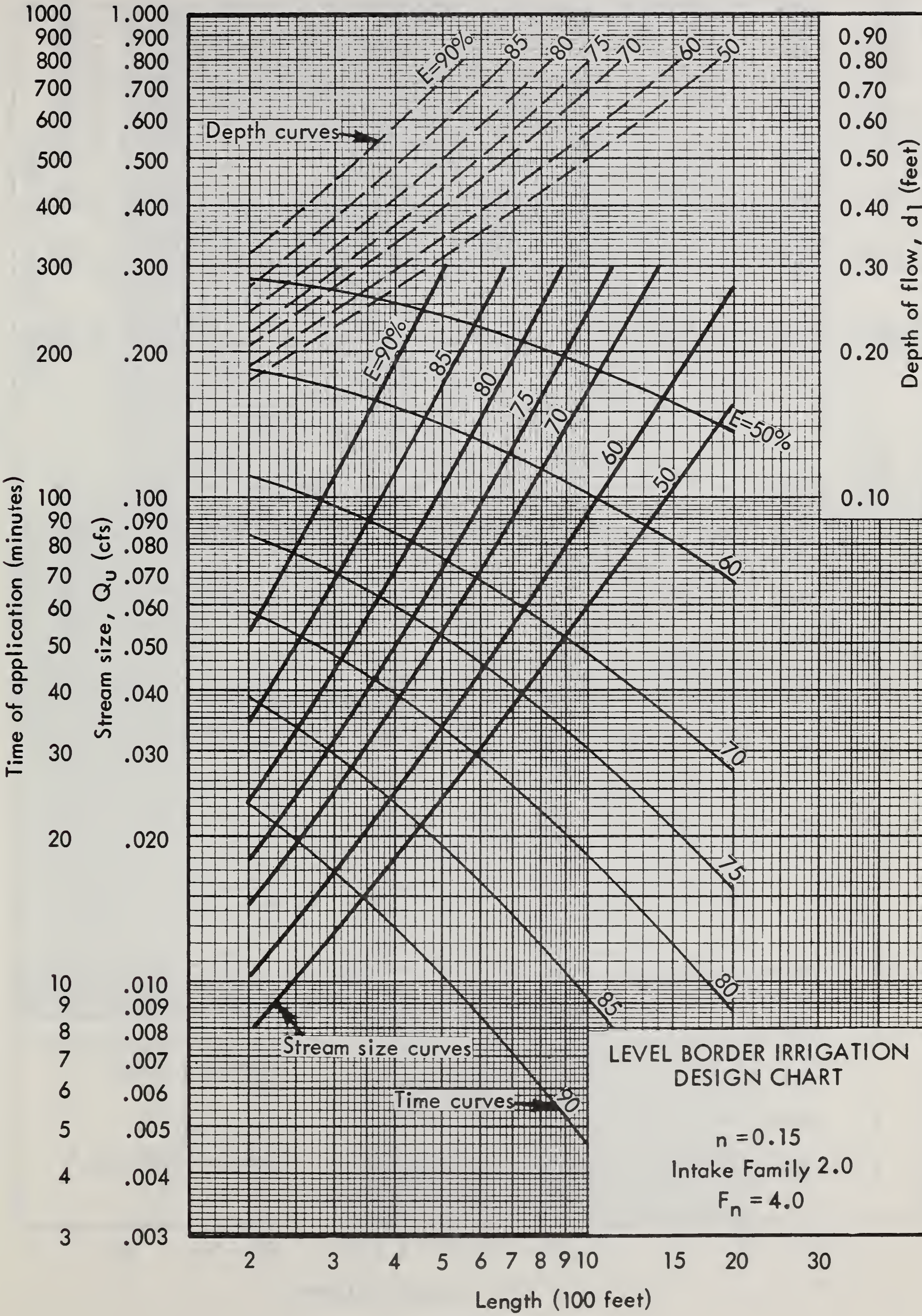
20
30
Length (100 feet)


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
85
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75
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60
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E=50%
1000
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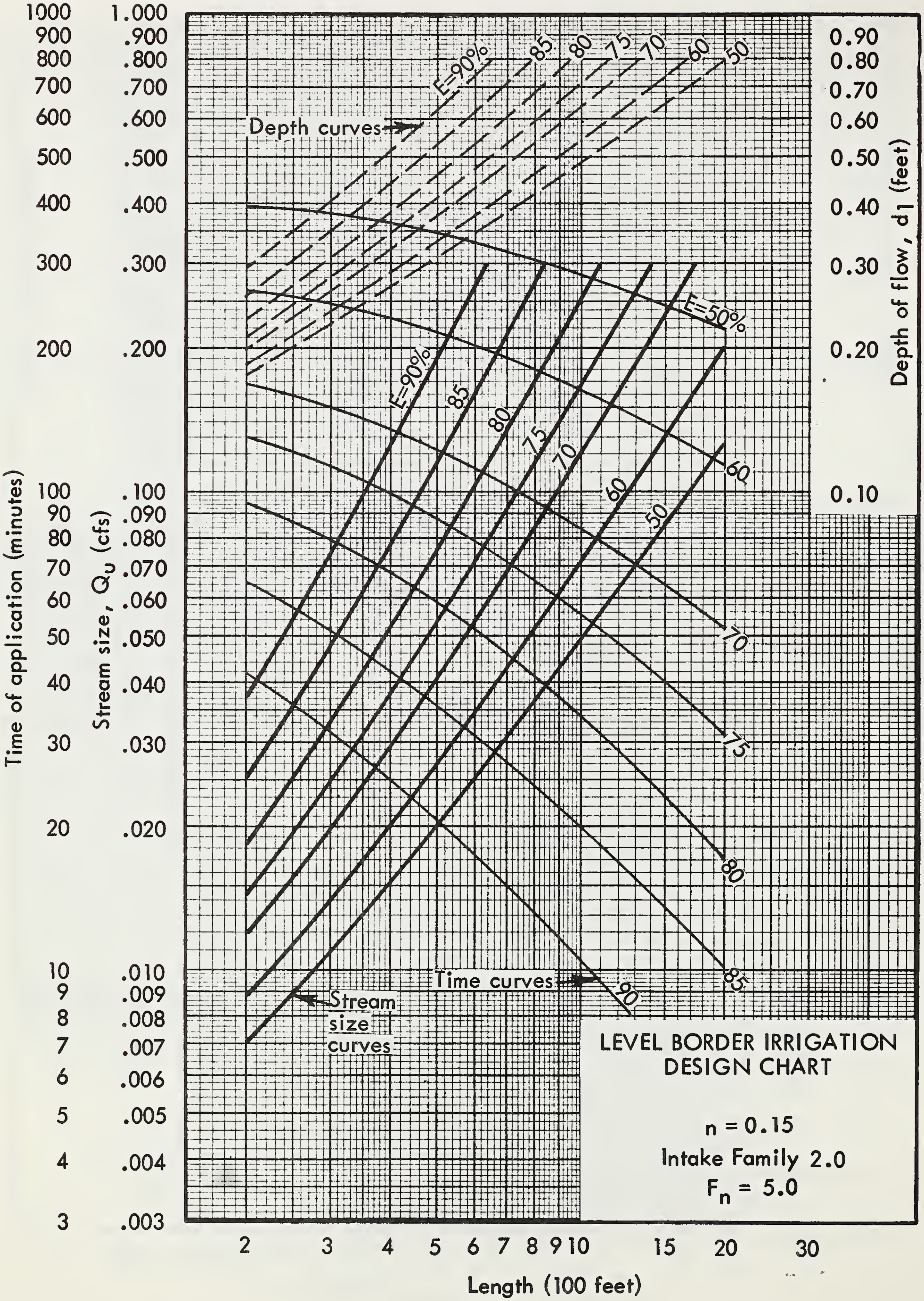
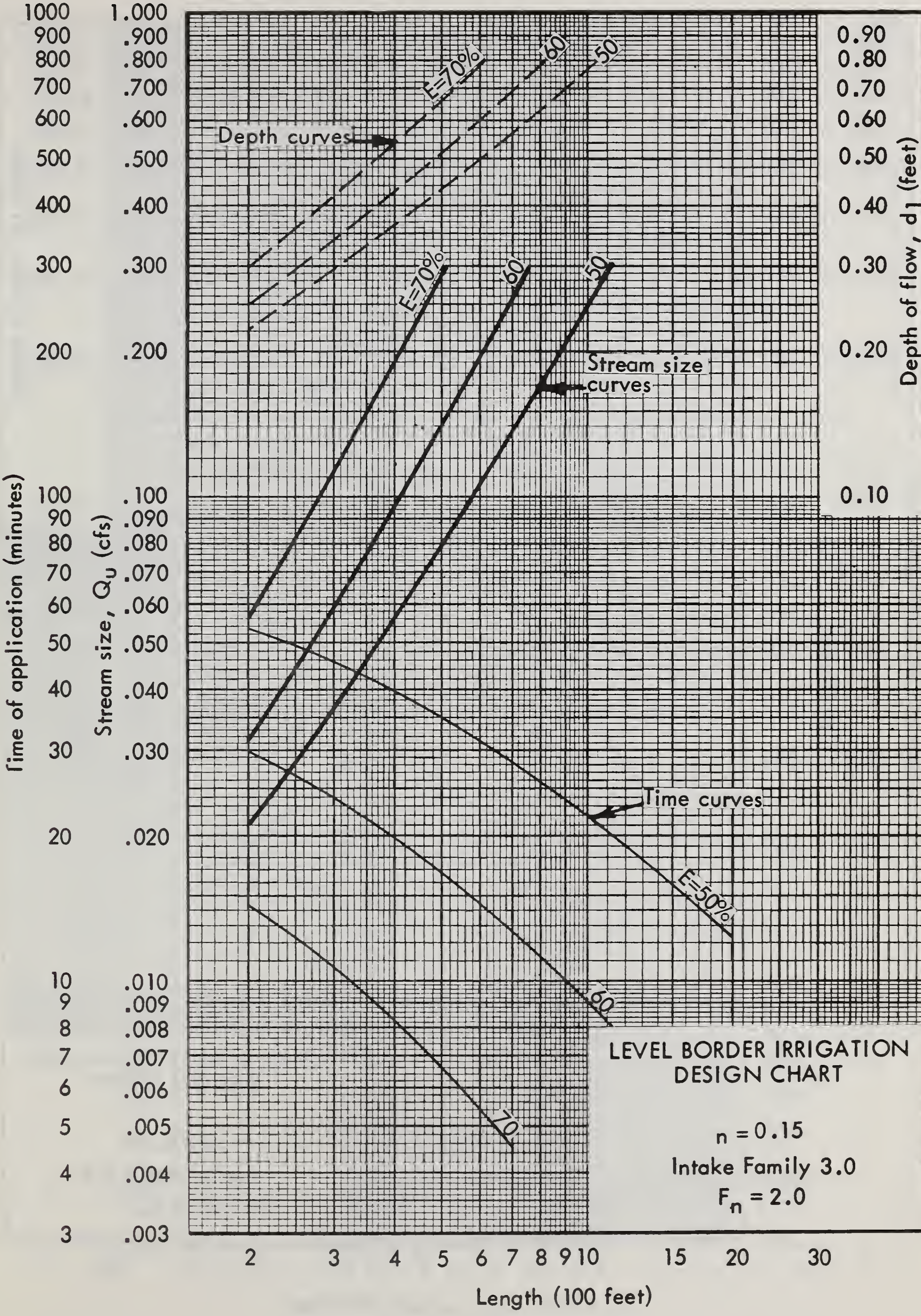
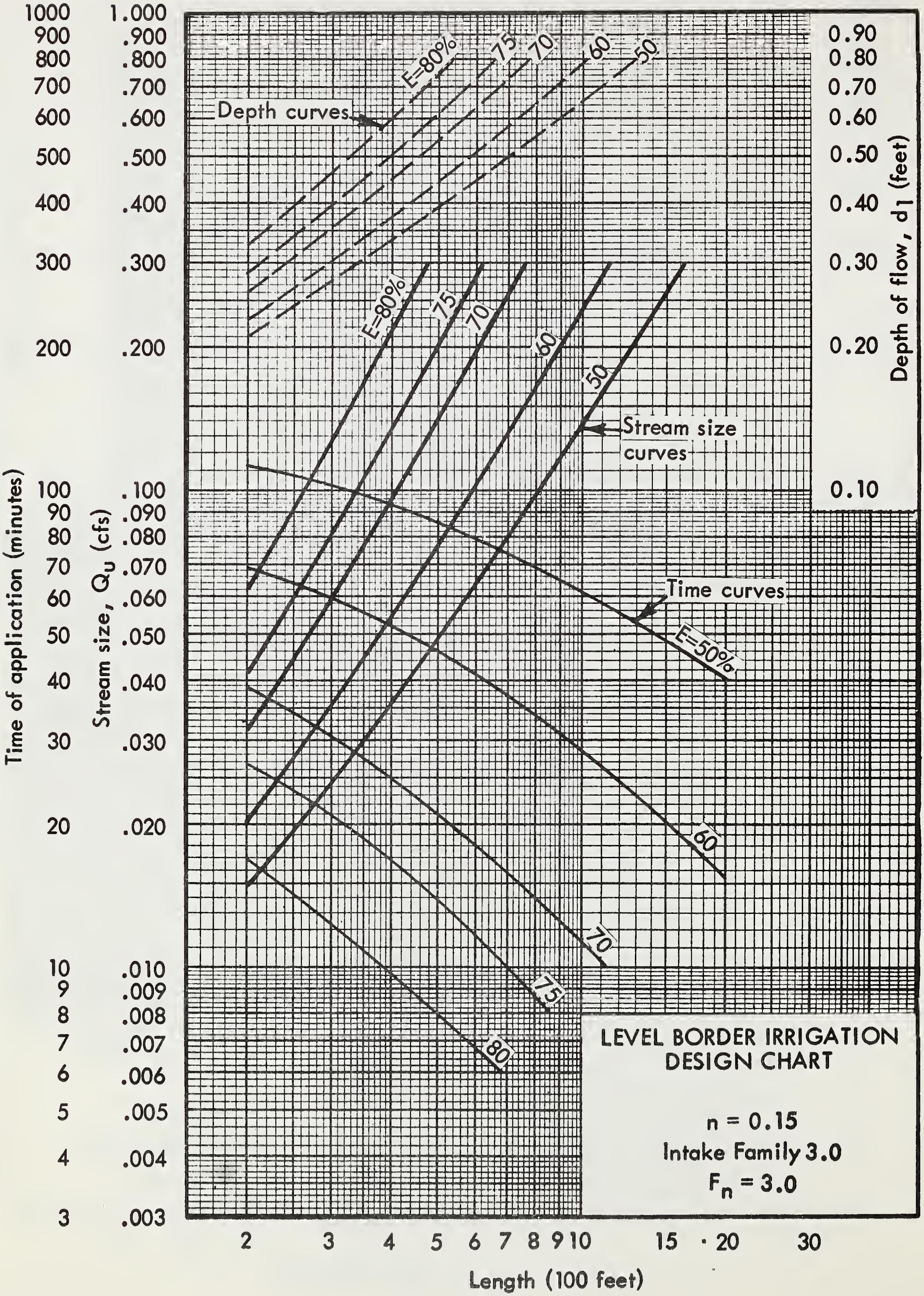
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30

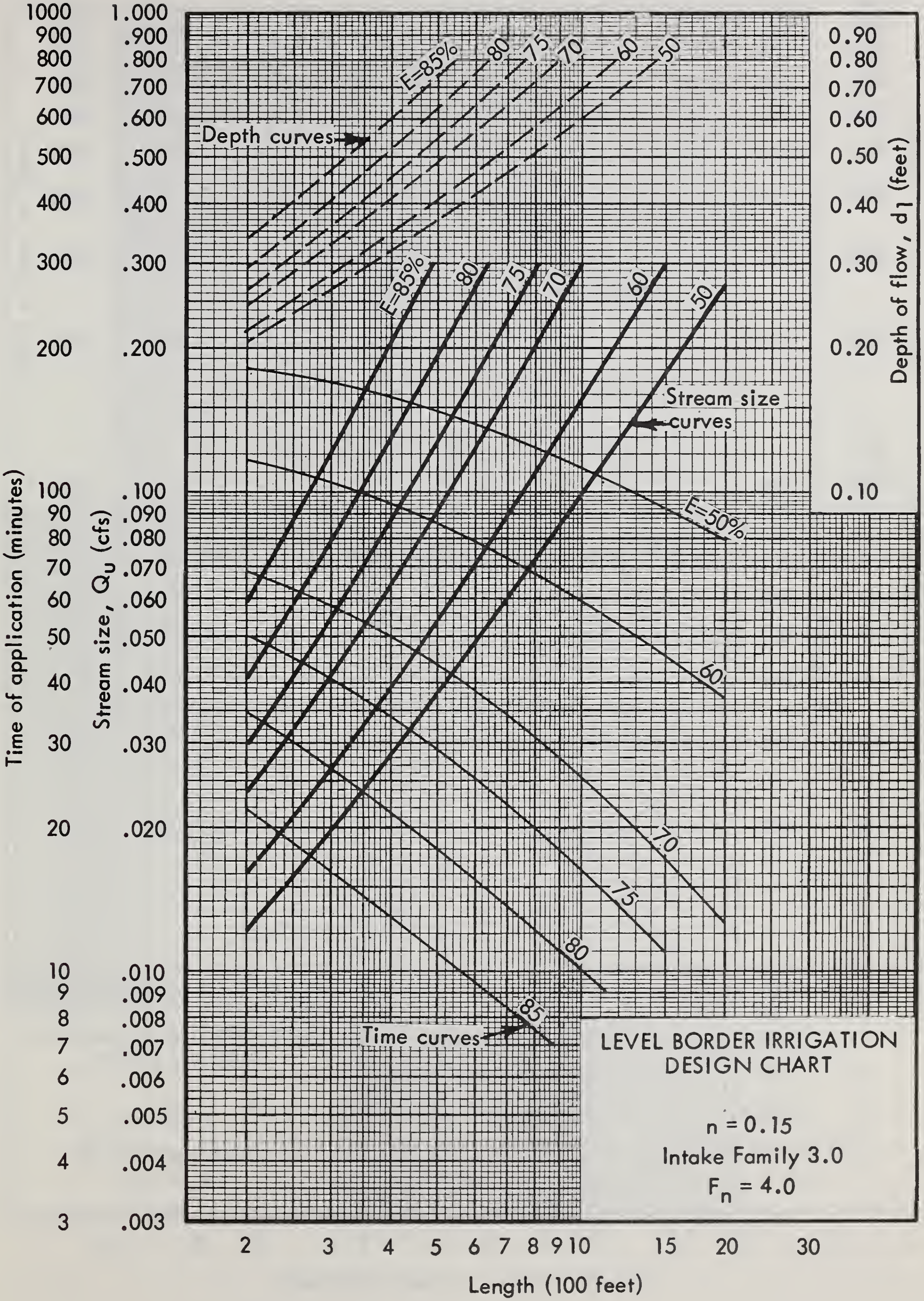

Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth curves
E=90%
85
80
75
70
60
50
E=50%
E=90%
85
80
75
70
60
50
60
70
75
80
85
90
Time curves
Stream size curves
Length (100 feet)
2
3
4
5
6
7
8
9
10
15
20
30
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 5.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
E=70%
60
50
Stream size curves
Time curves
E=50%
70
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 2.0



Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
80
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 3.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
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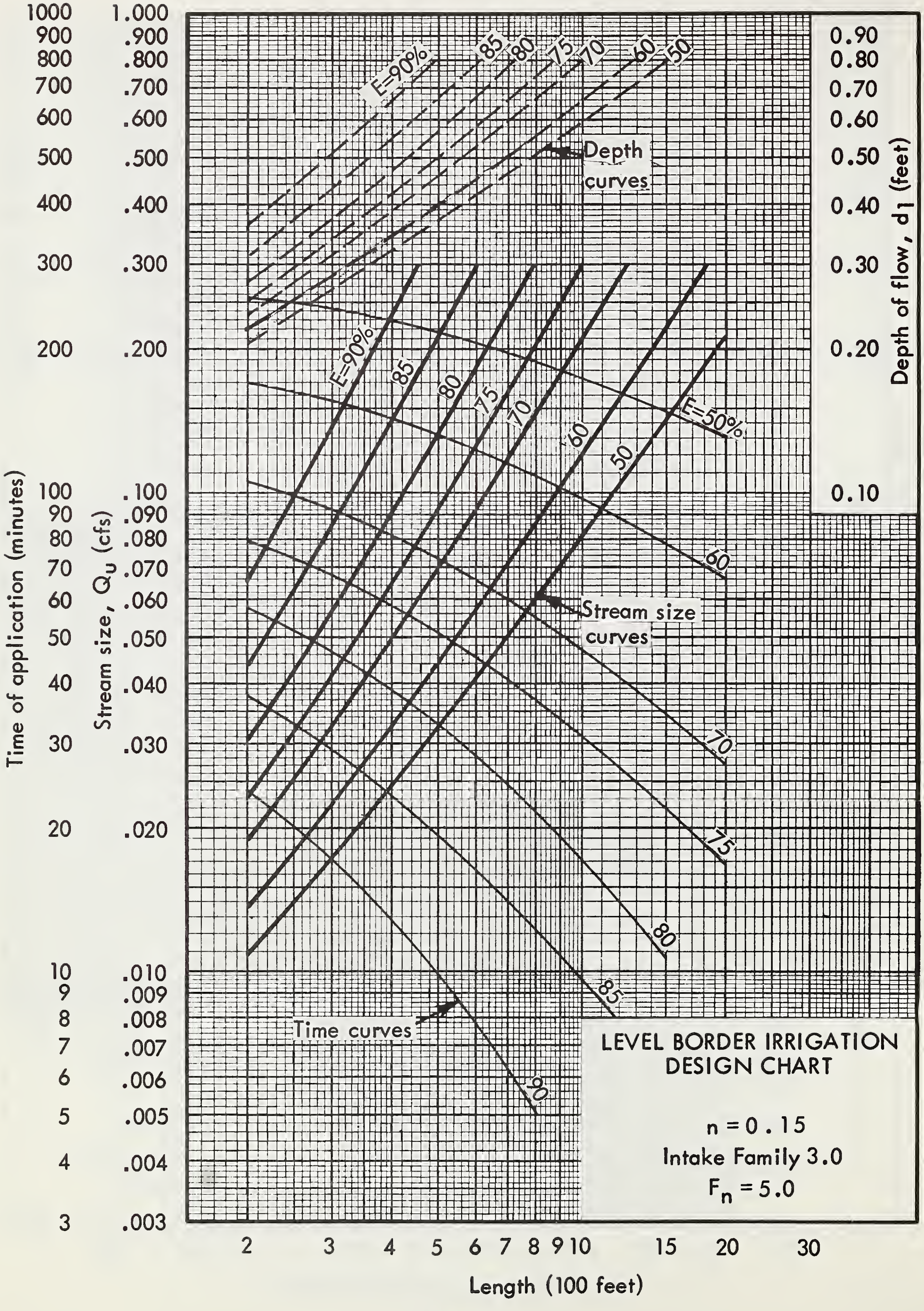
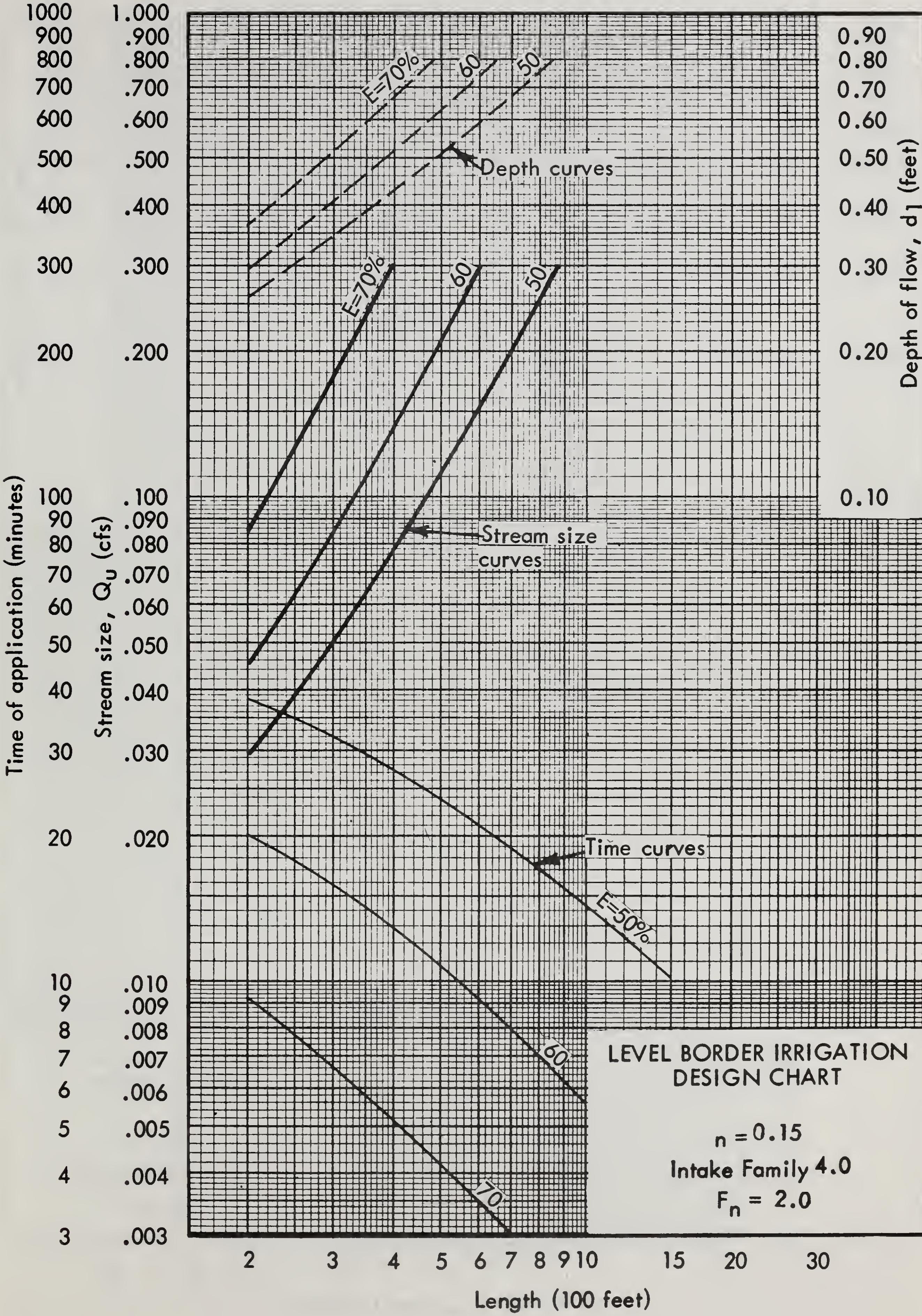

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=90%
85
80
75
70
60
50
Depth curves
E=50%
Stream size curves
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 5.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=70%
60
50
E=50%
70
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
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4
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1.000
.900
.800
.700
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.500
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.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
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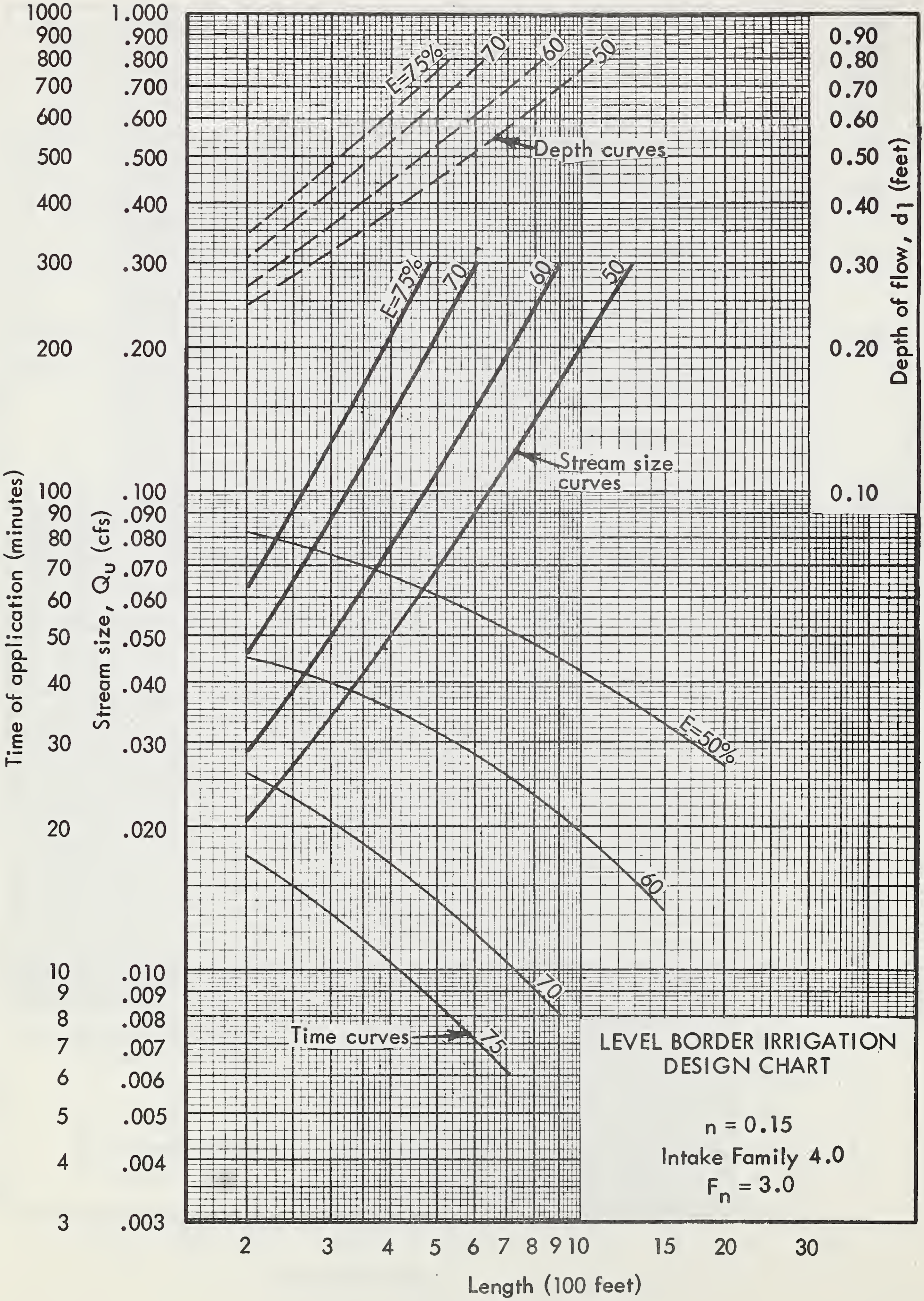
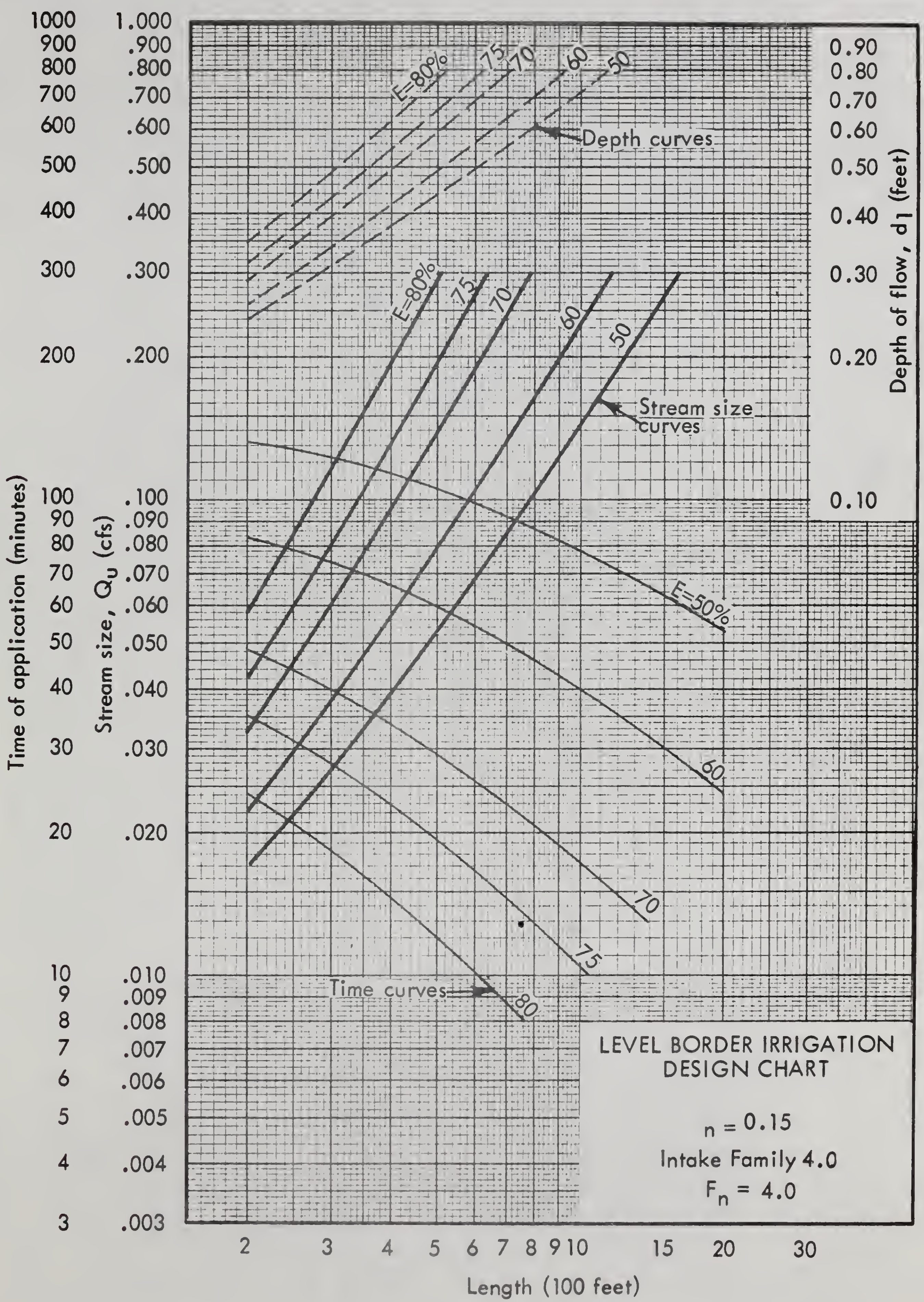
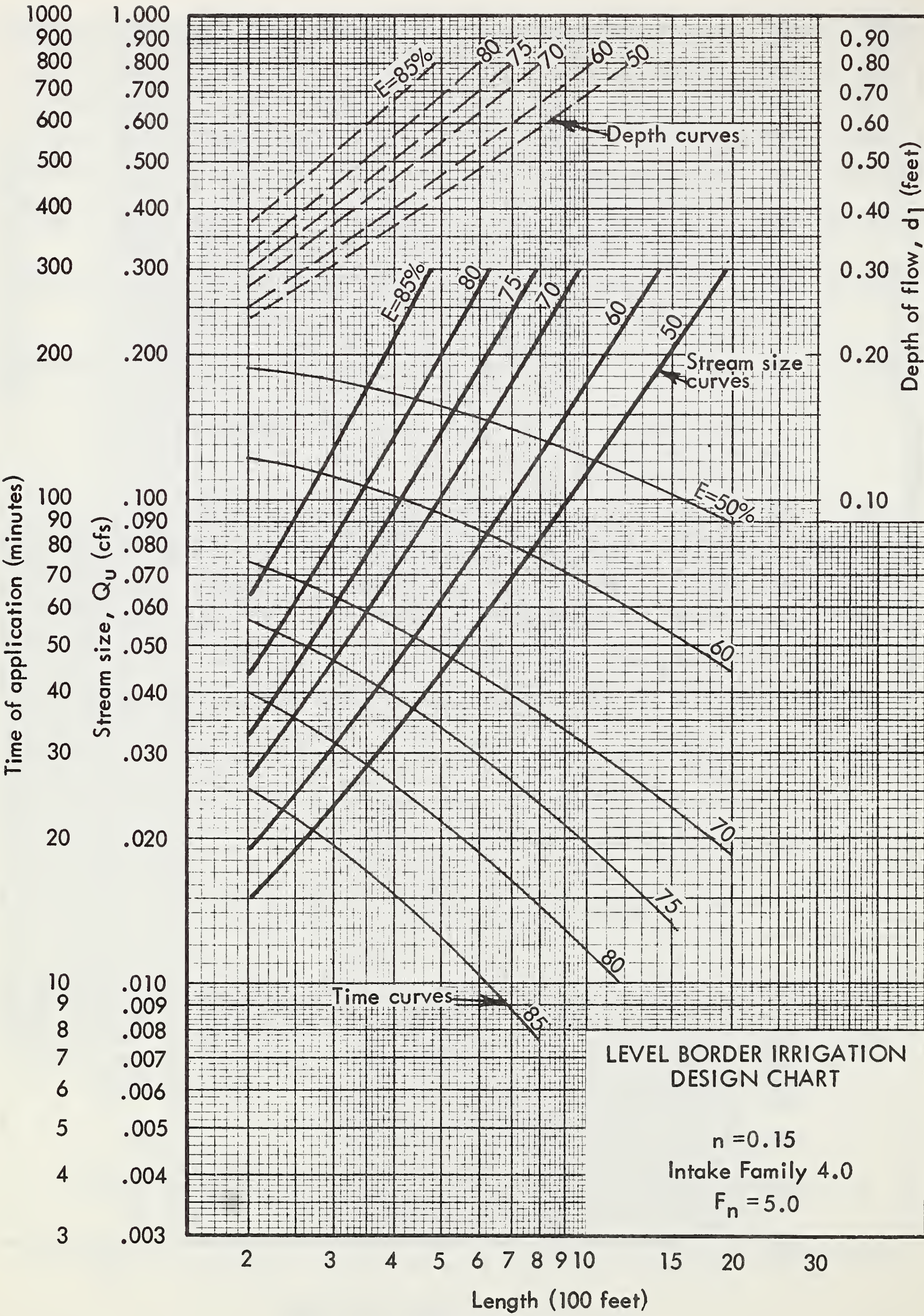
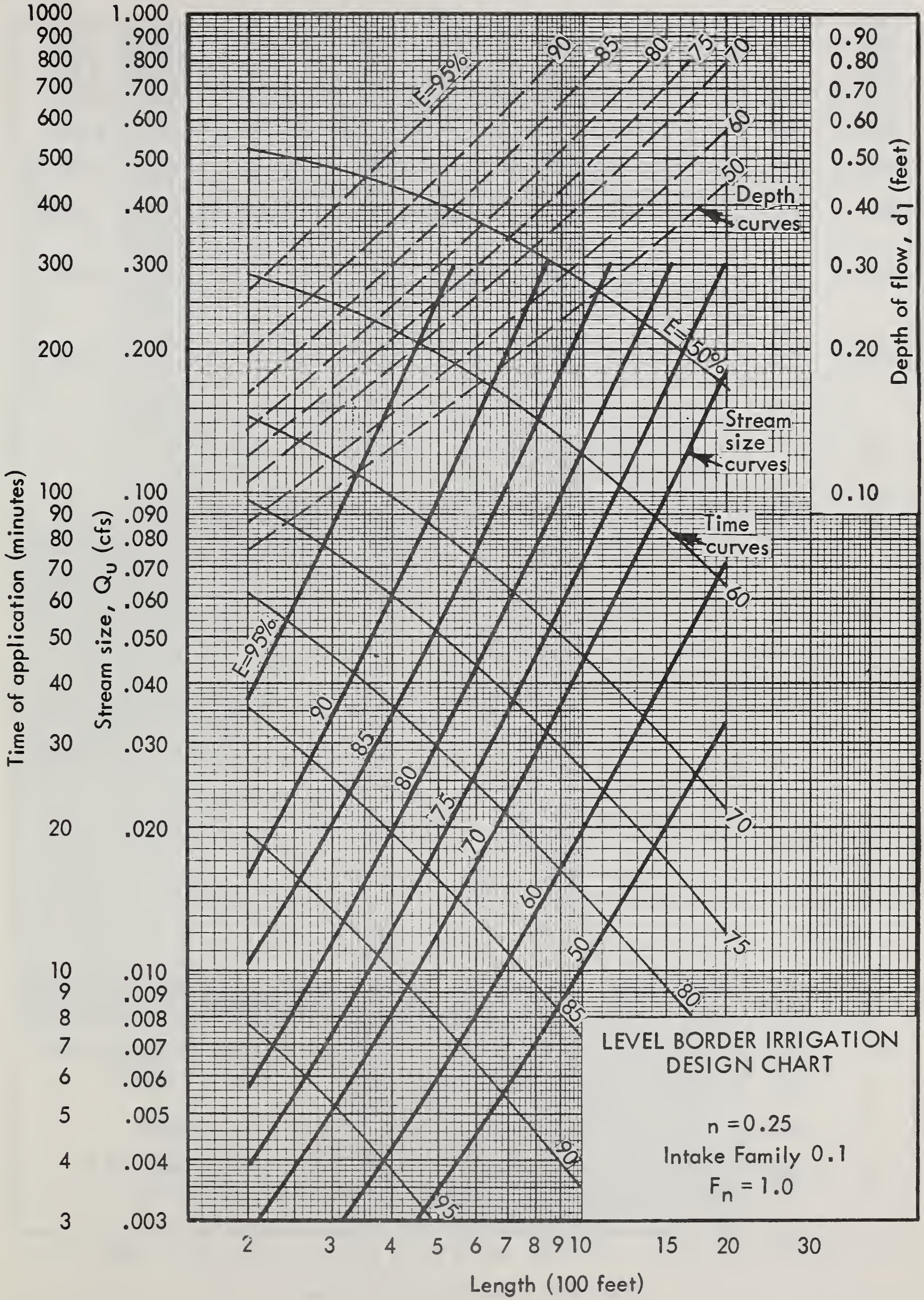
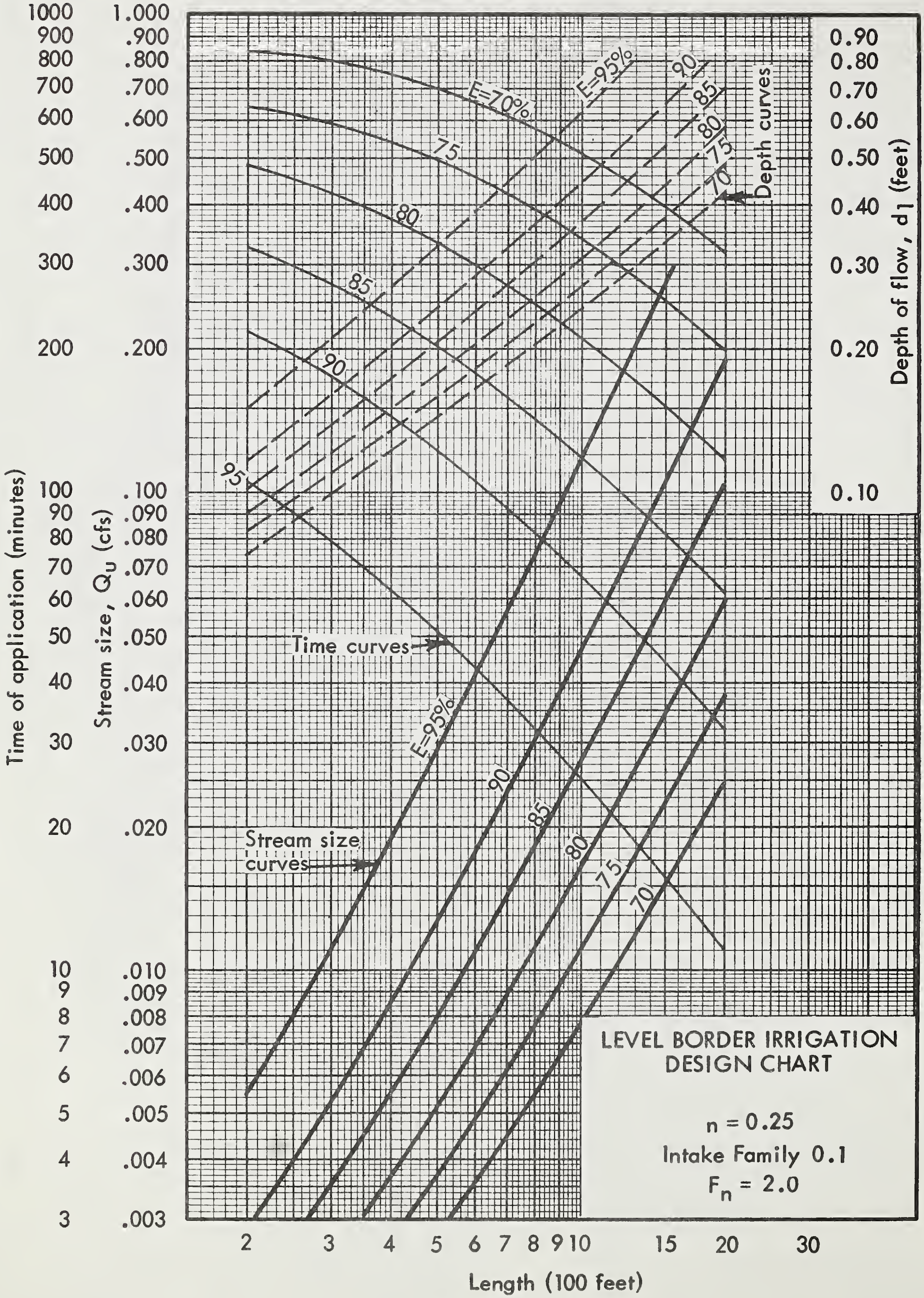

Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=75%
70
60
50
E=50%
75
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 3.0


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 4.0


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 4.0
F_n =5.0



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.1
F_n = 1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=95%
E=50%


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.1
F_n = 2.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Stream size curves
Depth curves
E=70%
75
80
85
90
95
E=95%
90
85
80
75
70
E=95%
90
85
80
75
70
1000
900
800
700
600
500
400
300
200
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.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
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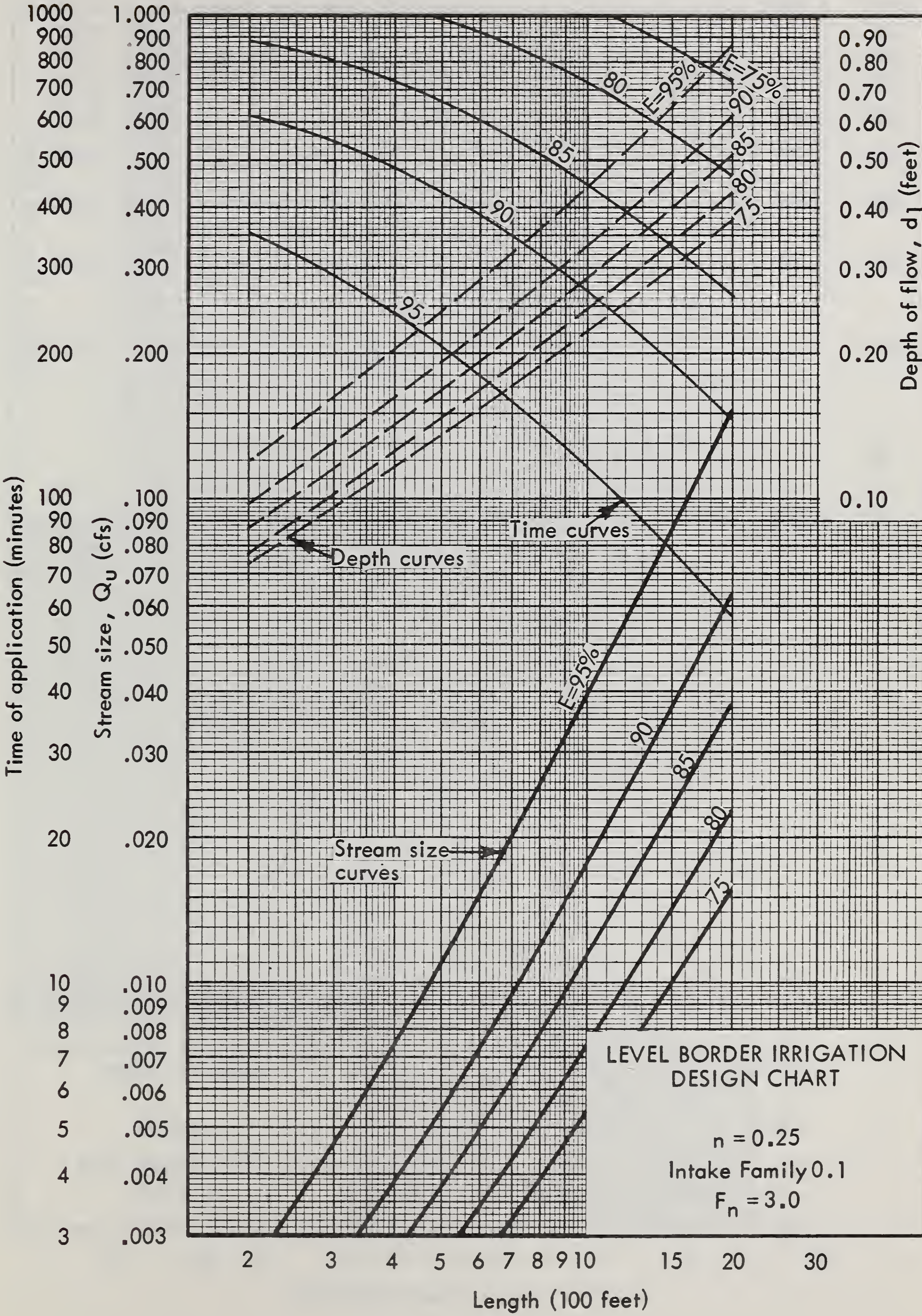
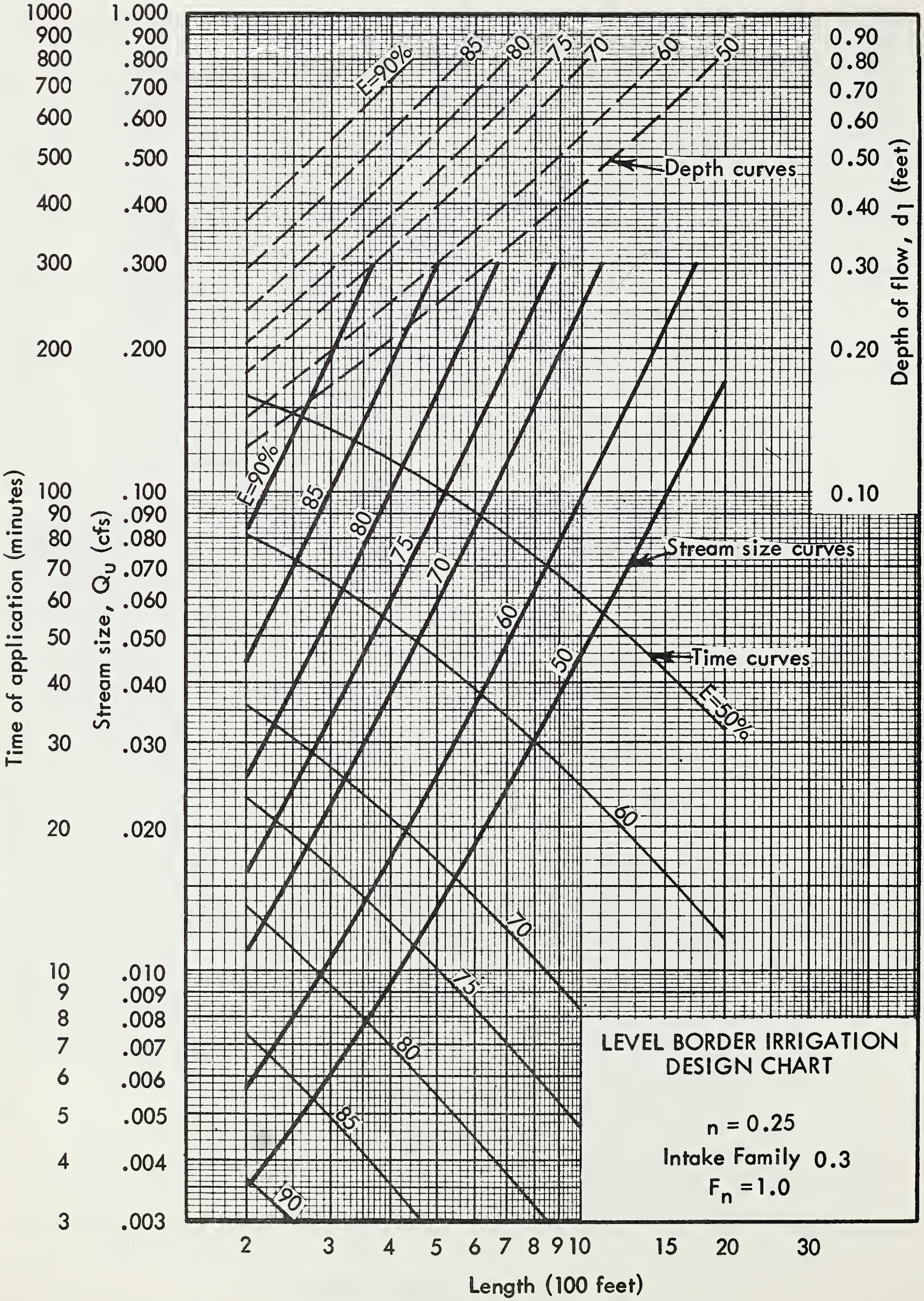

LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.1
$F_n = 3.0$
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Depth curves
Stream size curves
E=95%
E=75%
90
85
80
75
95


LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
E=50%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
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.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
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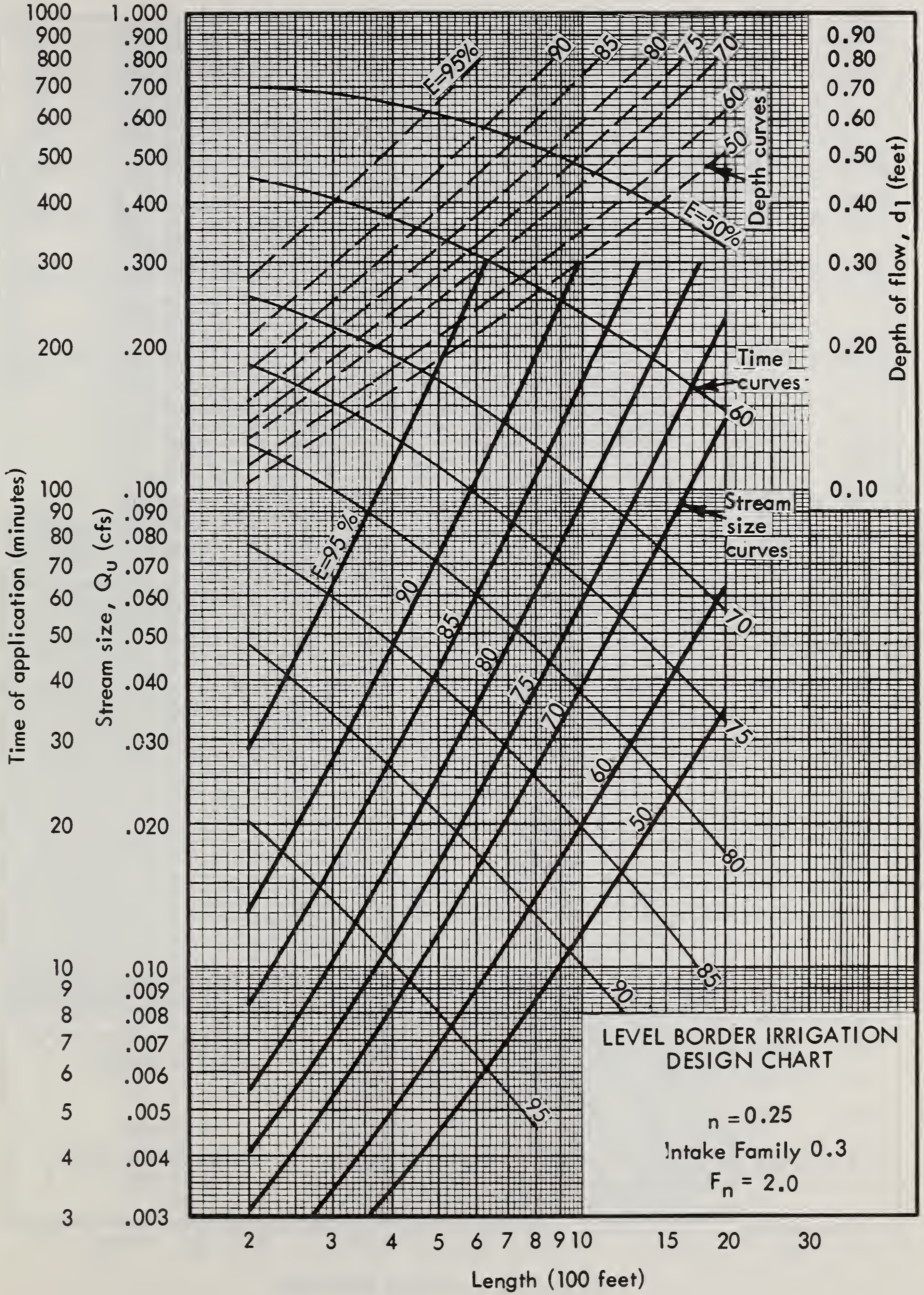
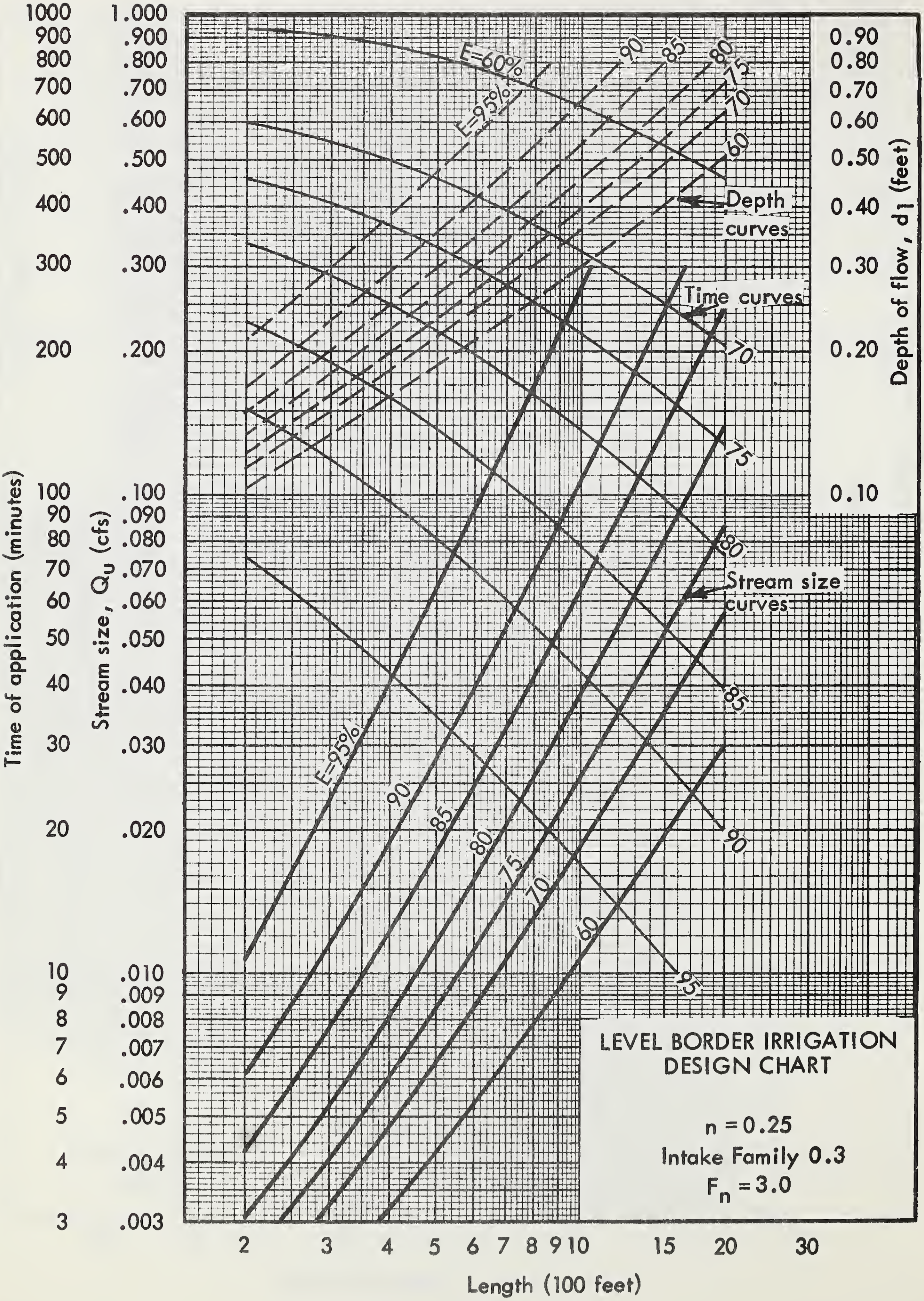
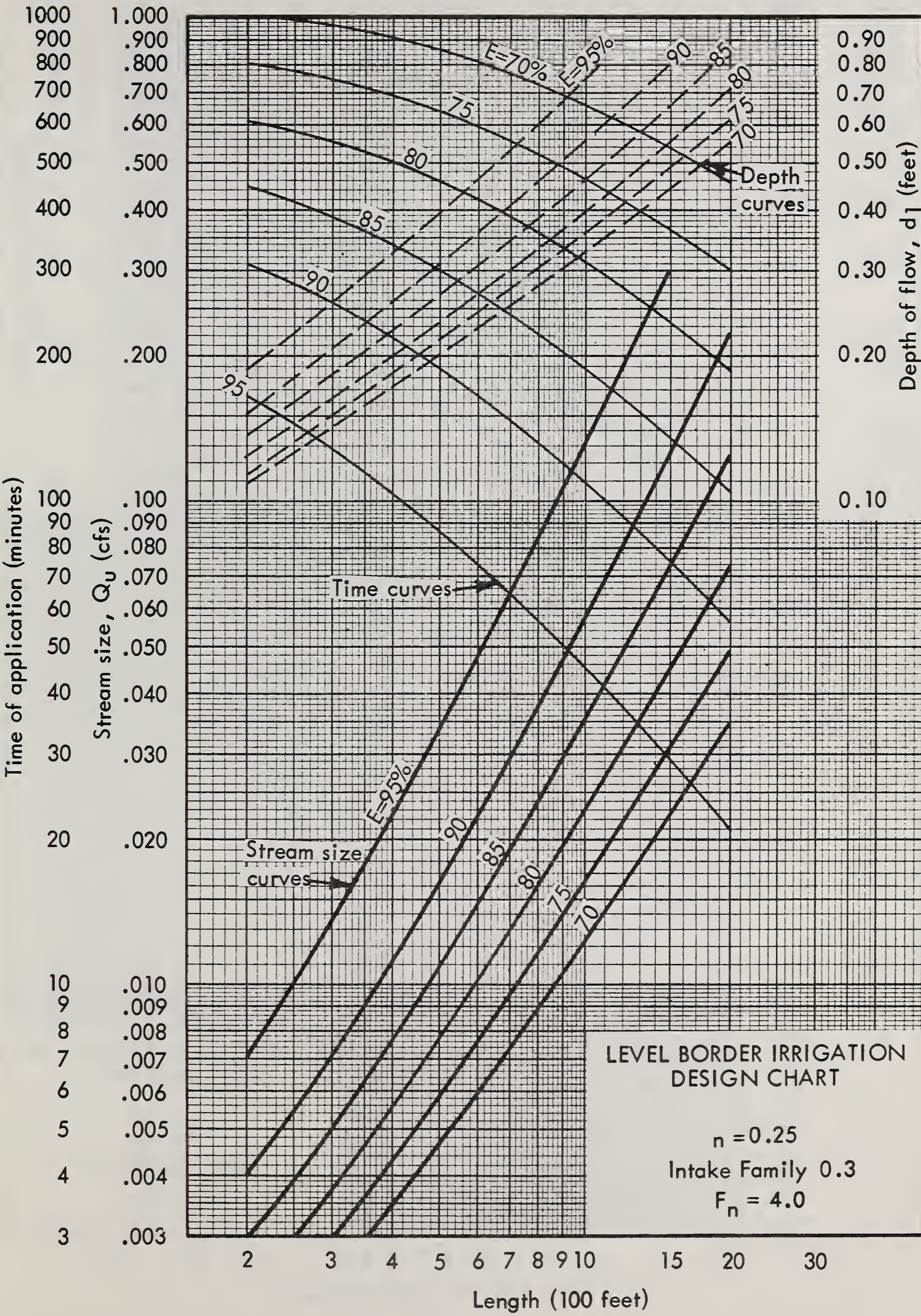

Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=95%
90
85
80
75
70
60
50
Depth curves
E=50%
Time curves
60
Stream size curves
E=95 %
90
85
80
75
70
60
50
70
75
80
85
90
95
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 2.0



Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=60%
E=95%
90
85
80
75
70
60
Depth curves
Time curves
70
75
80
85
90
95
Stream size curves
E=95%
90
85
80
75
70
60
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 3.0



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=70%
75
80
85
90
95
E=95%
90
85
80
75
70
E=95%
90
85
80
75
70
1000
900
800
700
600
500
400
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200
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1.000
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.008
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.004
.003
0.90
0.80
0.70
0.60
0.50
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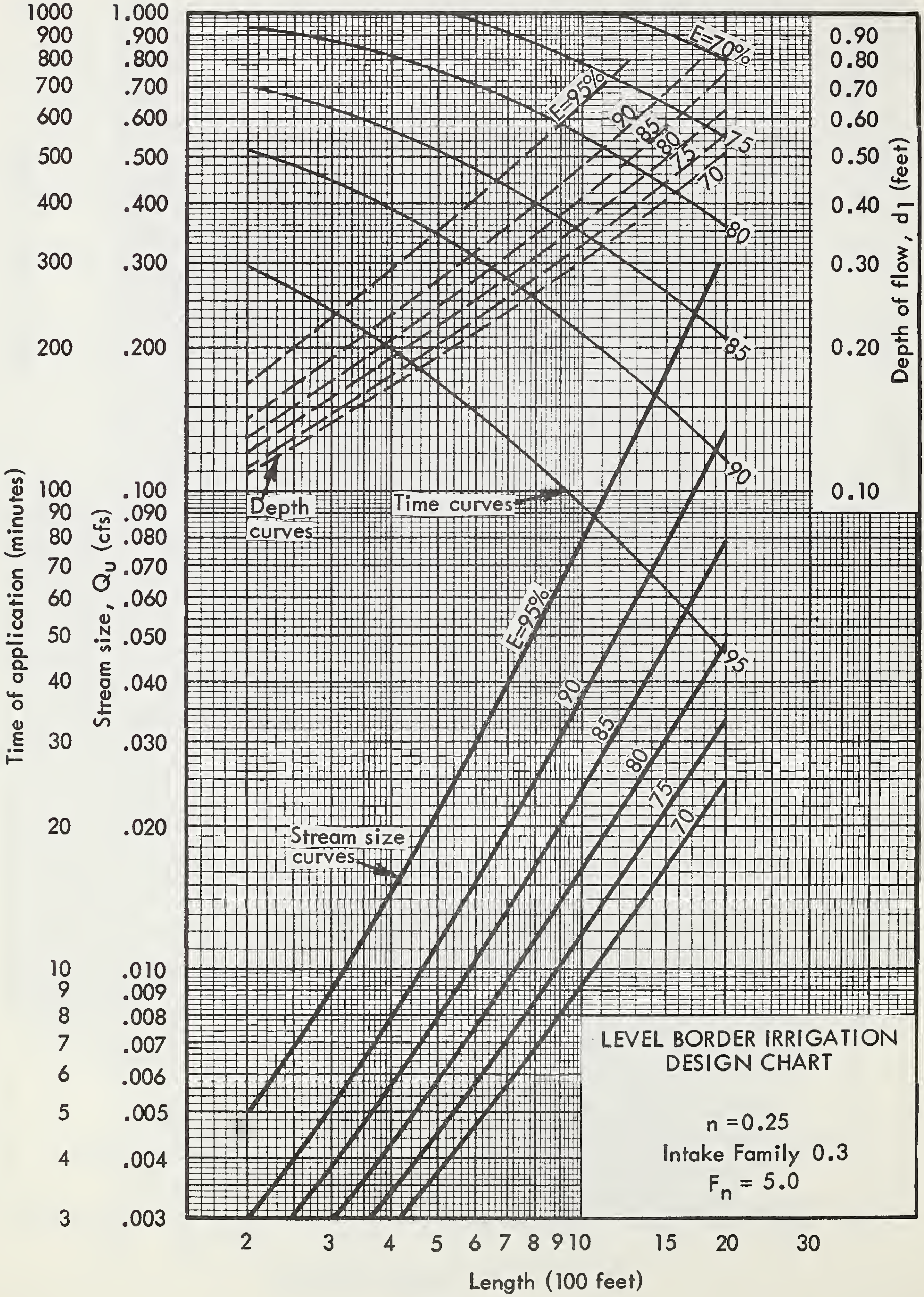

LEVEL BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 0.3
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=70%
E=95%
90
85
80
75
70
95
1000
900
800
700
600
500
400
300
200
100
90
80
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0.90
0.80
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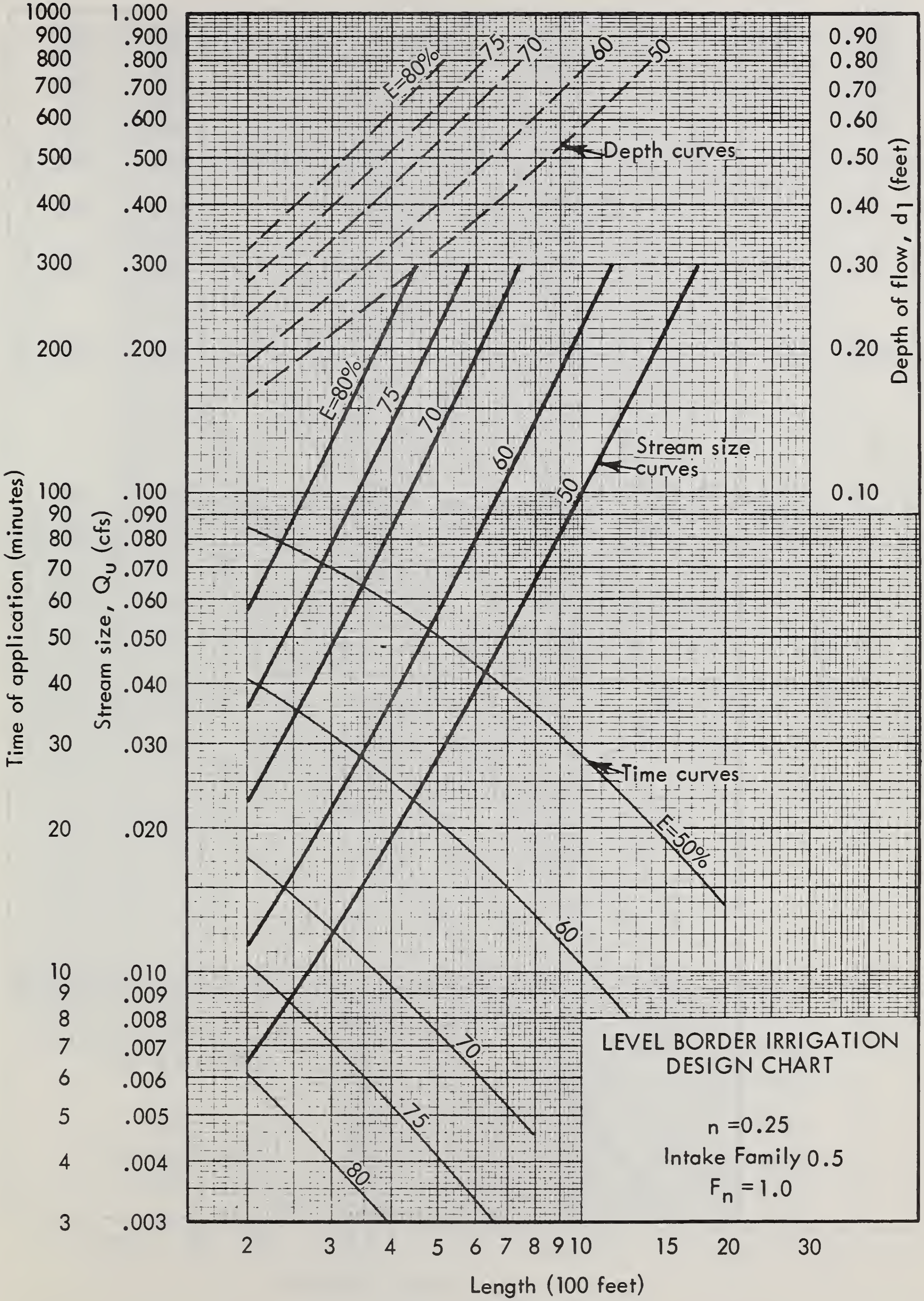

LEVEL BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 0.5
F_n =1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
1000
900
800
700
600
500
400
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200
100
90
80
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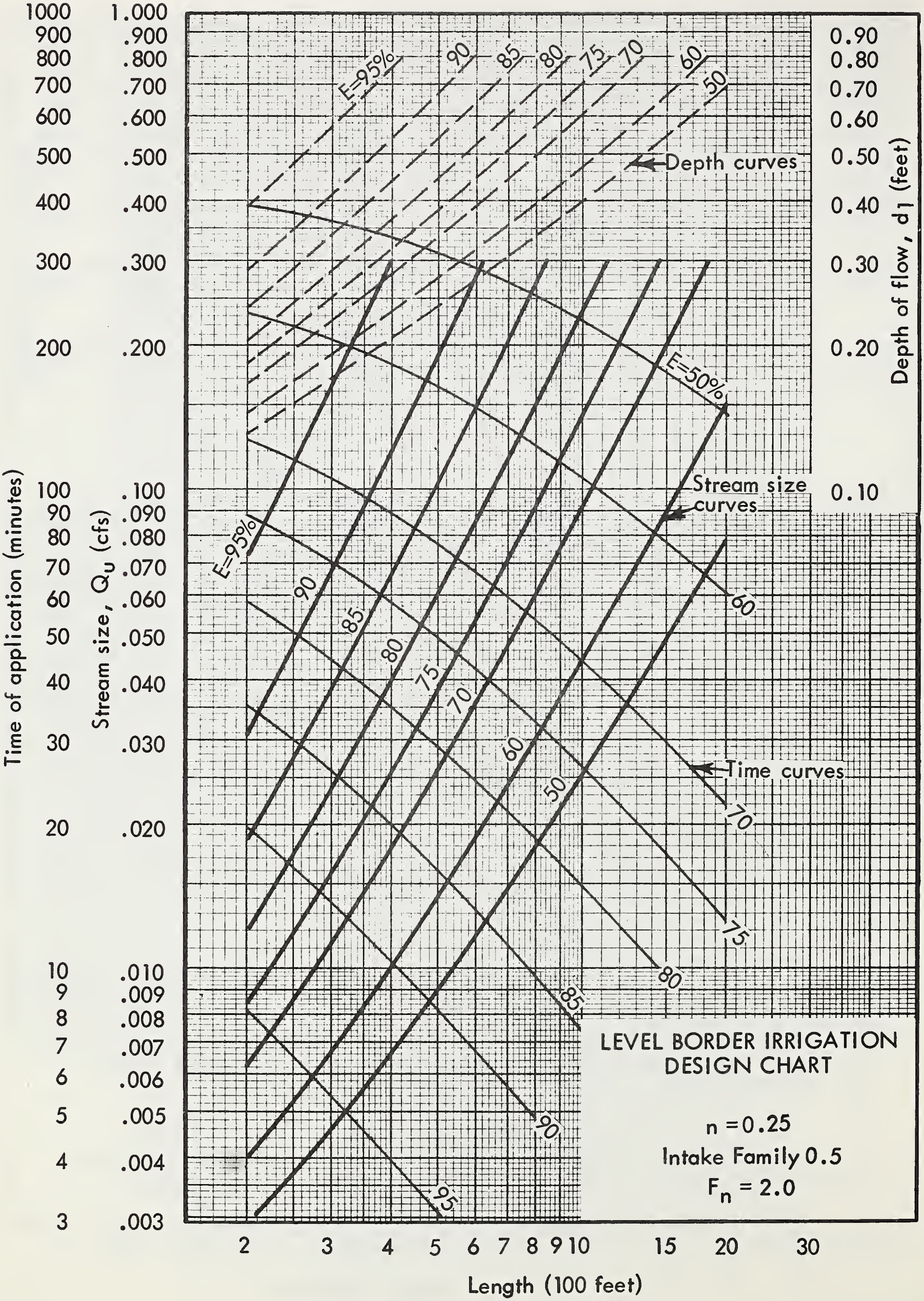
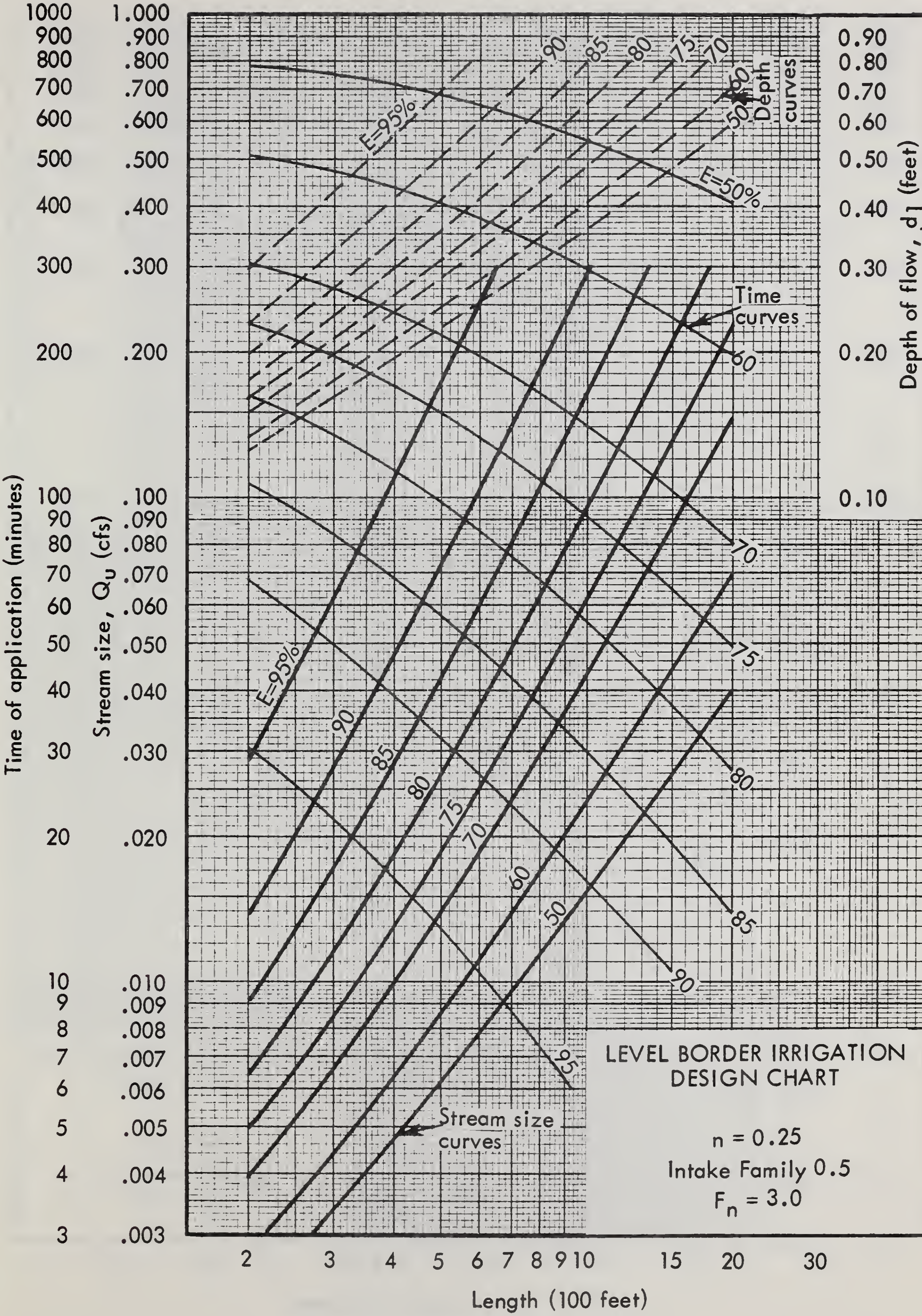
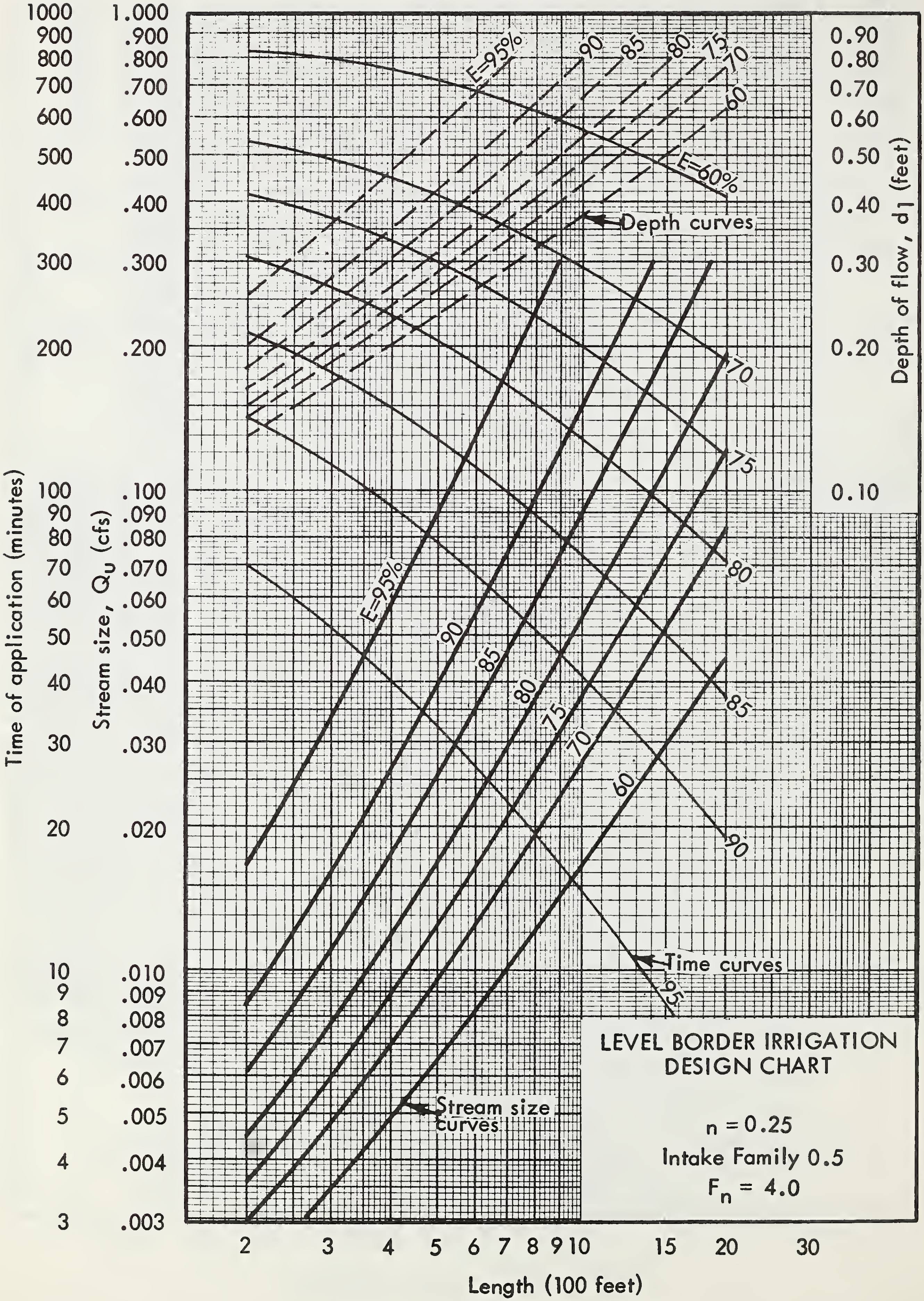
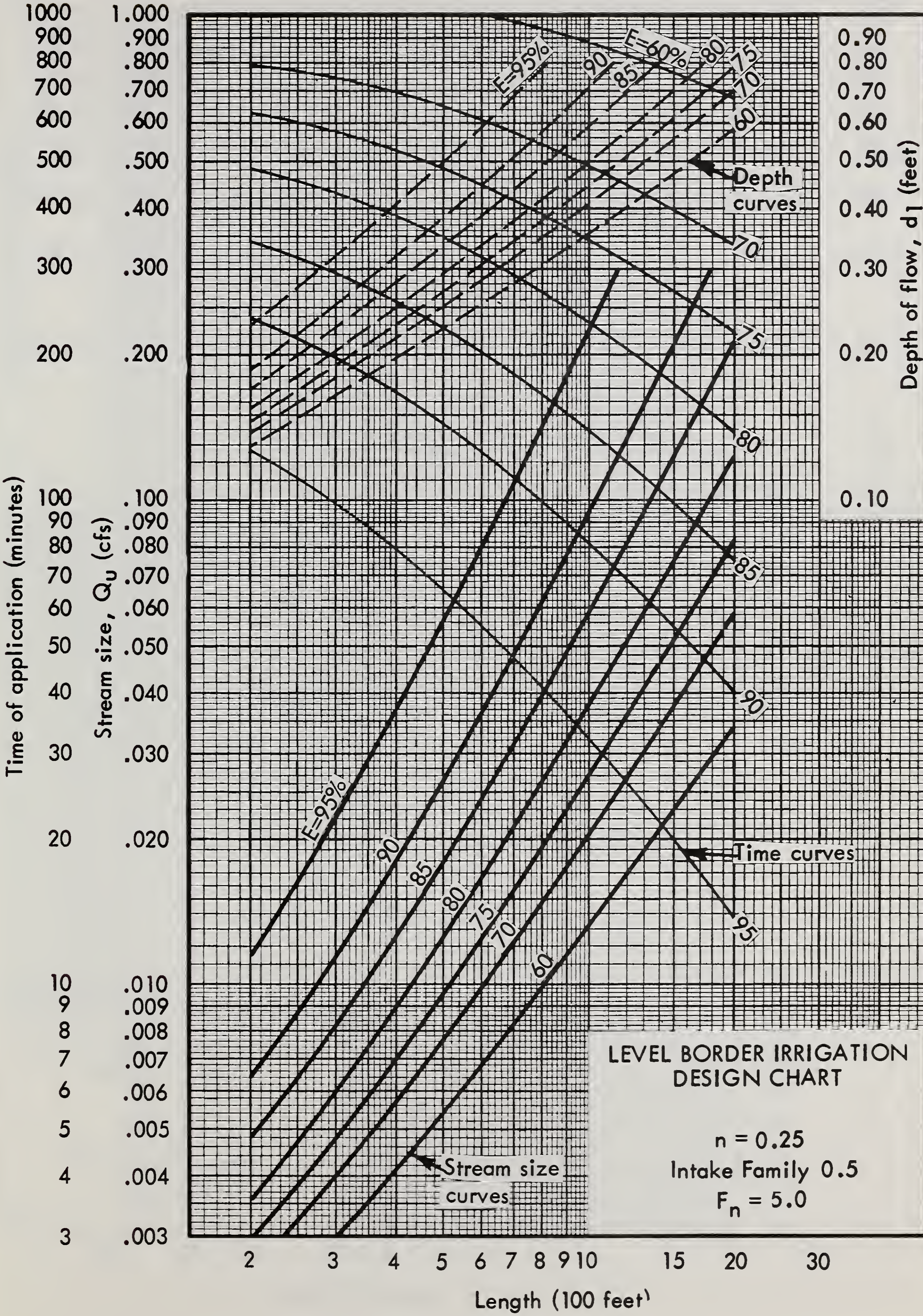


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=95%
90
85
80
75
70
60
50
Depth curves
E=50%
Stream size curves
Time curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 2.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 3.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Time curves
Stream size curves
Depth curves
E=95%
E=50%


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=95%
90
85
80
75
70
60
E=60%
Depth curves
Time curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 4.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
$F_n = 5.0$
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=95%
E=60%
1000
900
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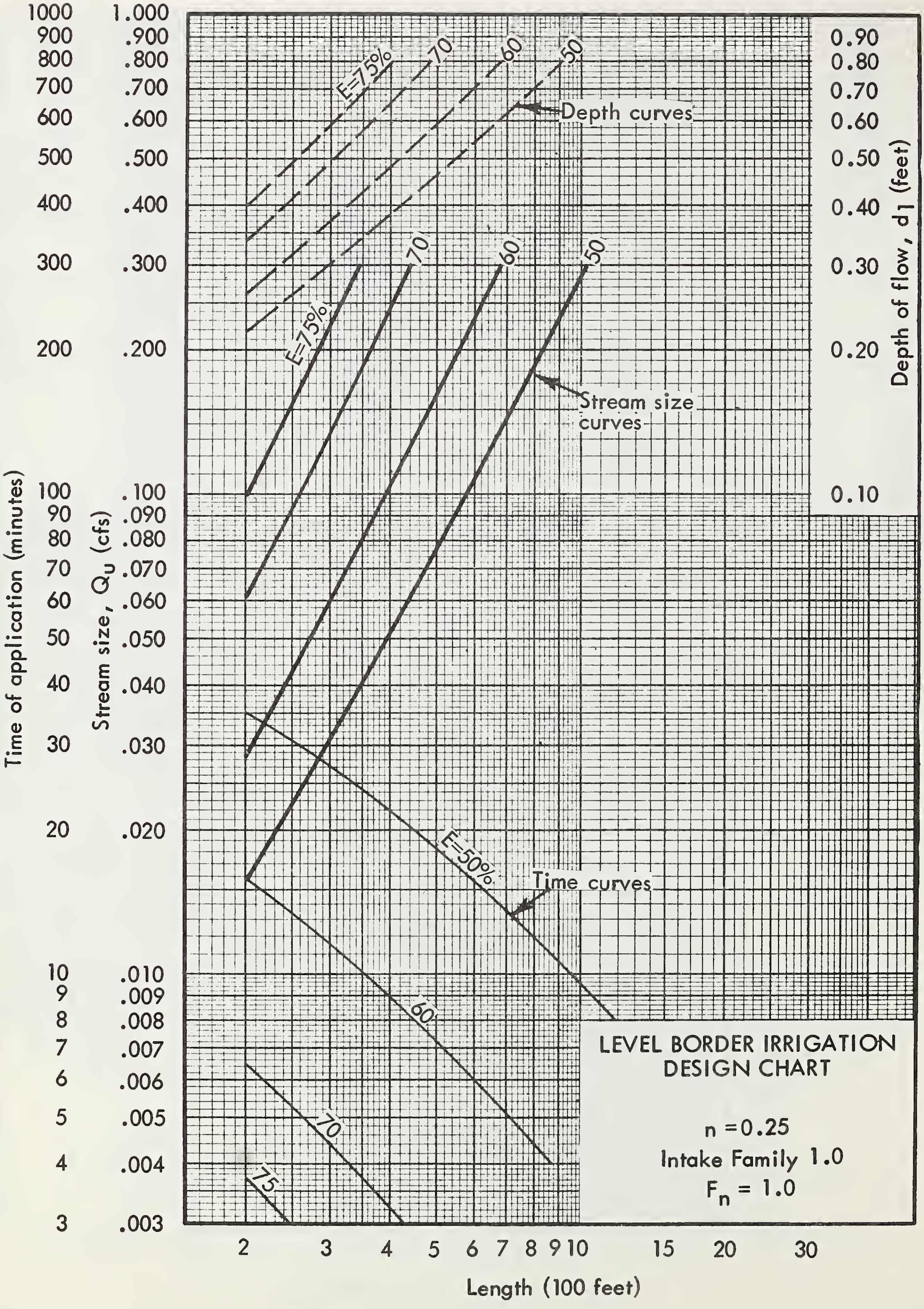
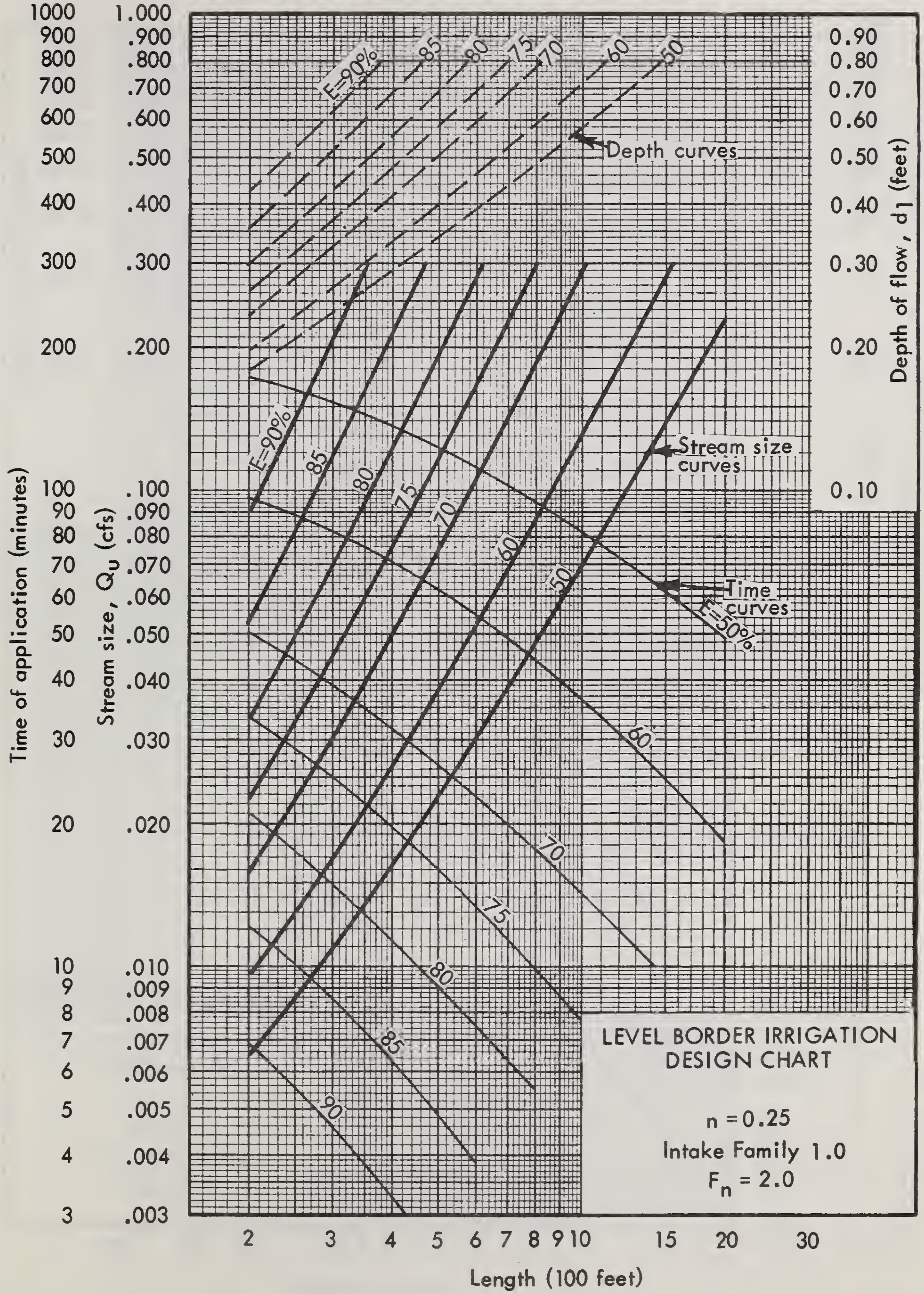
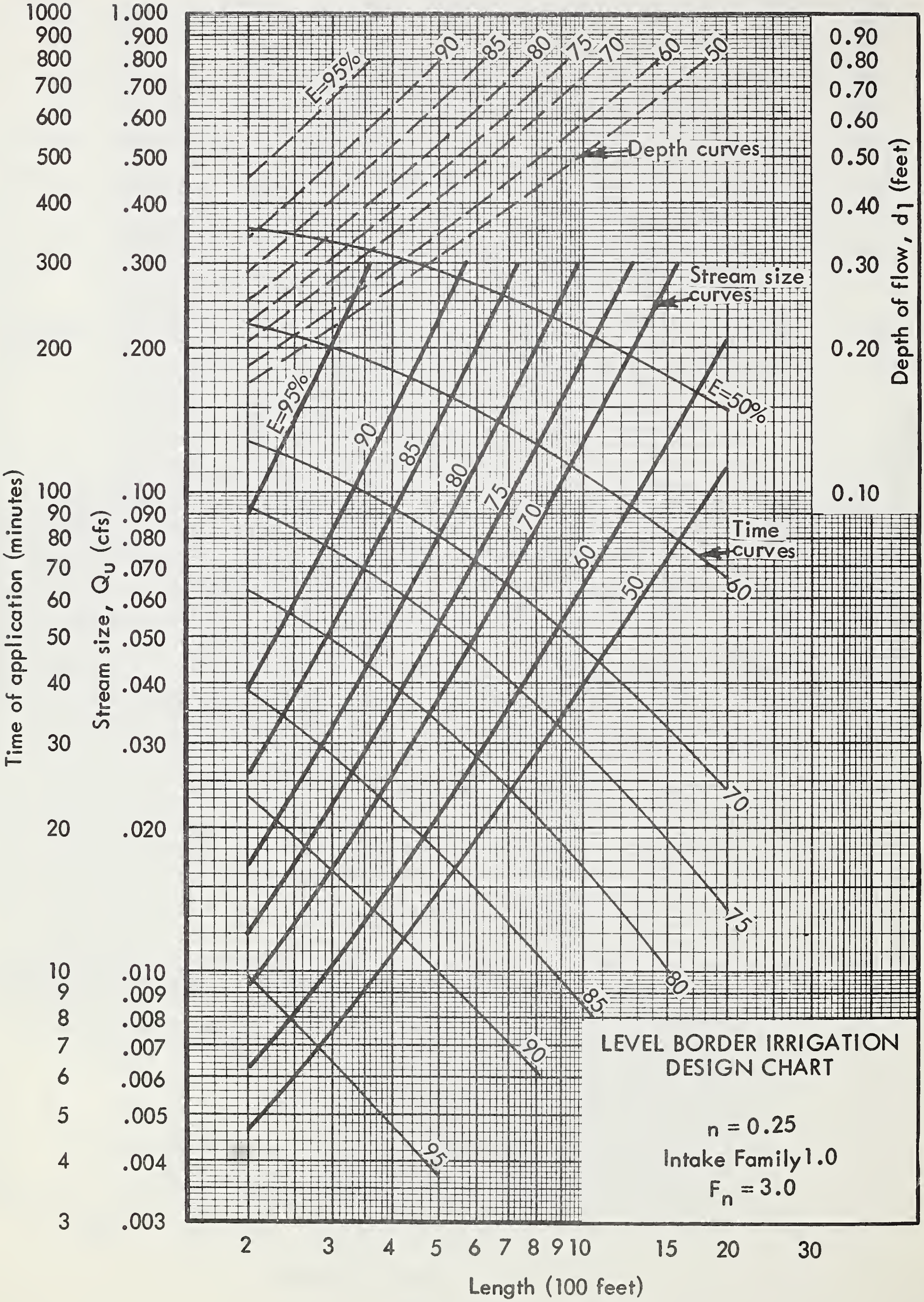


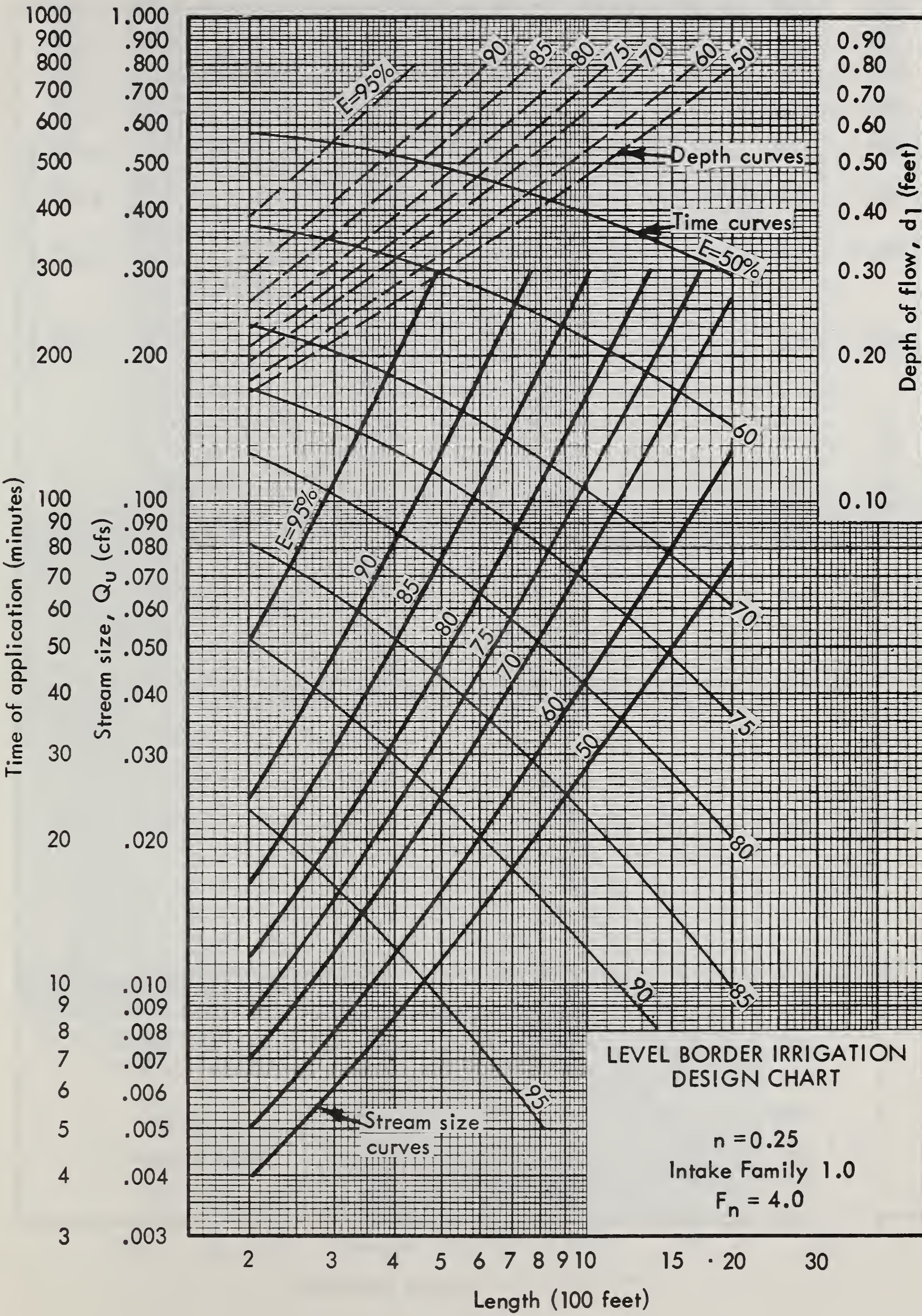
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 1.0
F_n = 1.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=75%
70
60
50
E=50%
75
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30



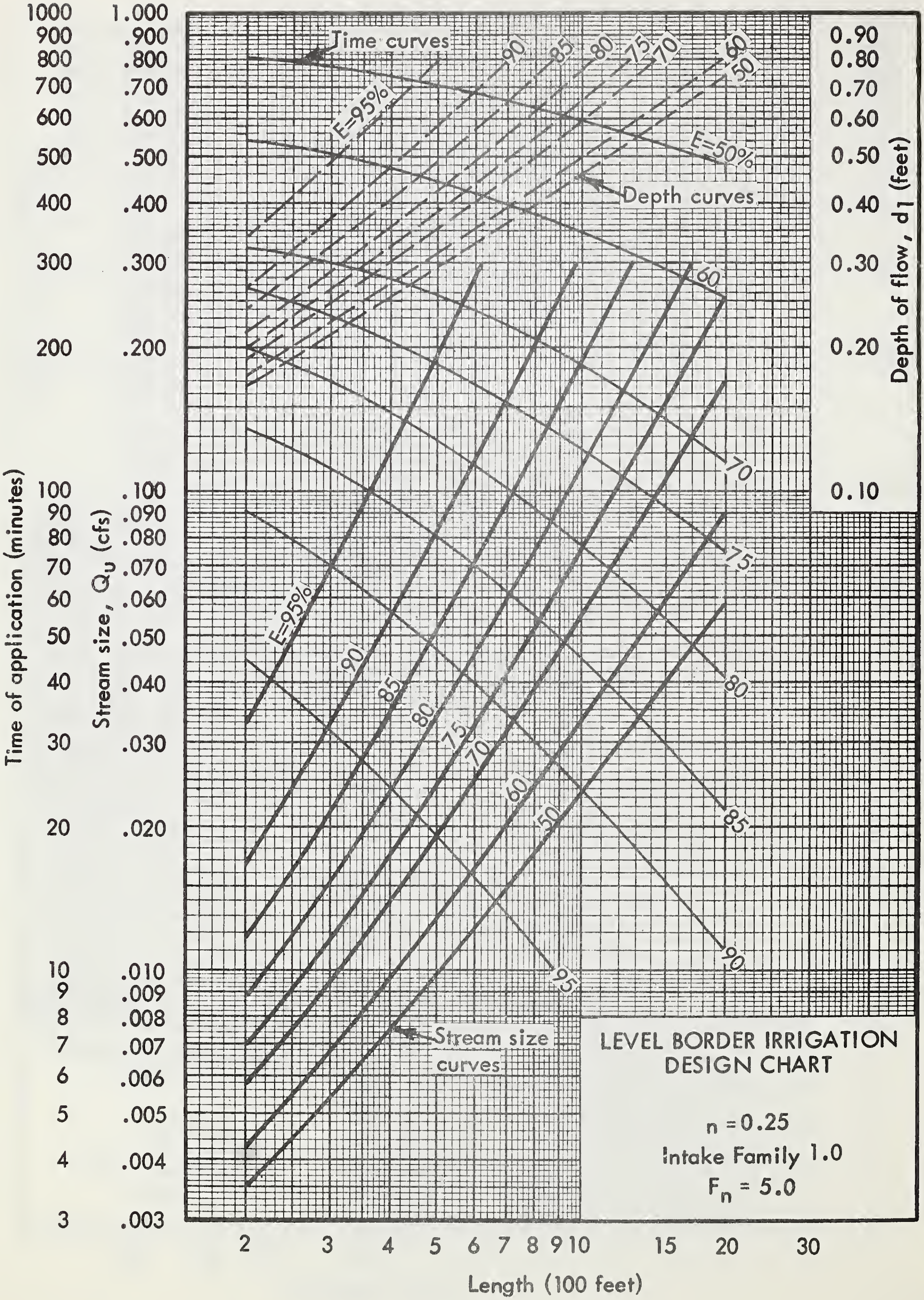
1000 1.000
900 .900
800 .800
700 .700
600 .600
500 .500
400 .400
300 .300
200 .200
100 .100
90 .090
80 .080
70 .070
60 .060
50 .050
40 .040
30 .030
20 .020
10 .010
9 .009
8 .008
7 .007
6 .006
5 .005
4 .004
3 .003
Time of application (minutes)
Stream size, Q_u (cfs)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth of flow, d_1 (feet)
E=90%
85
80
75
70
60
50
Depth curves
Stream size curves
Time curves
E=50%
2 3 4 5 6 7 8 9 10 15 20 30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
F_n = 2.0

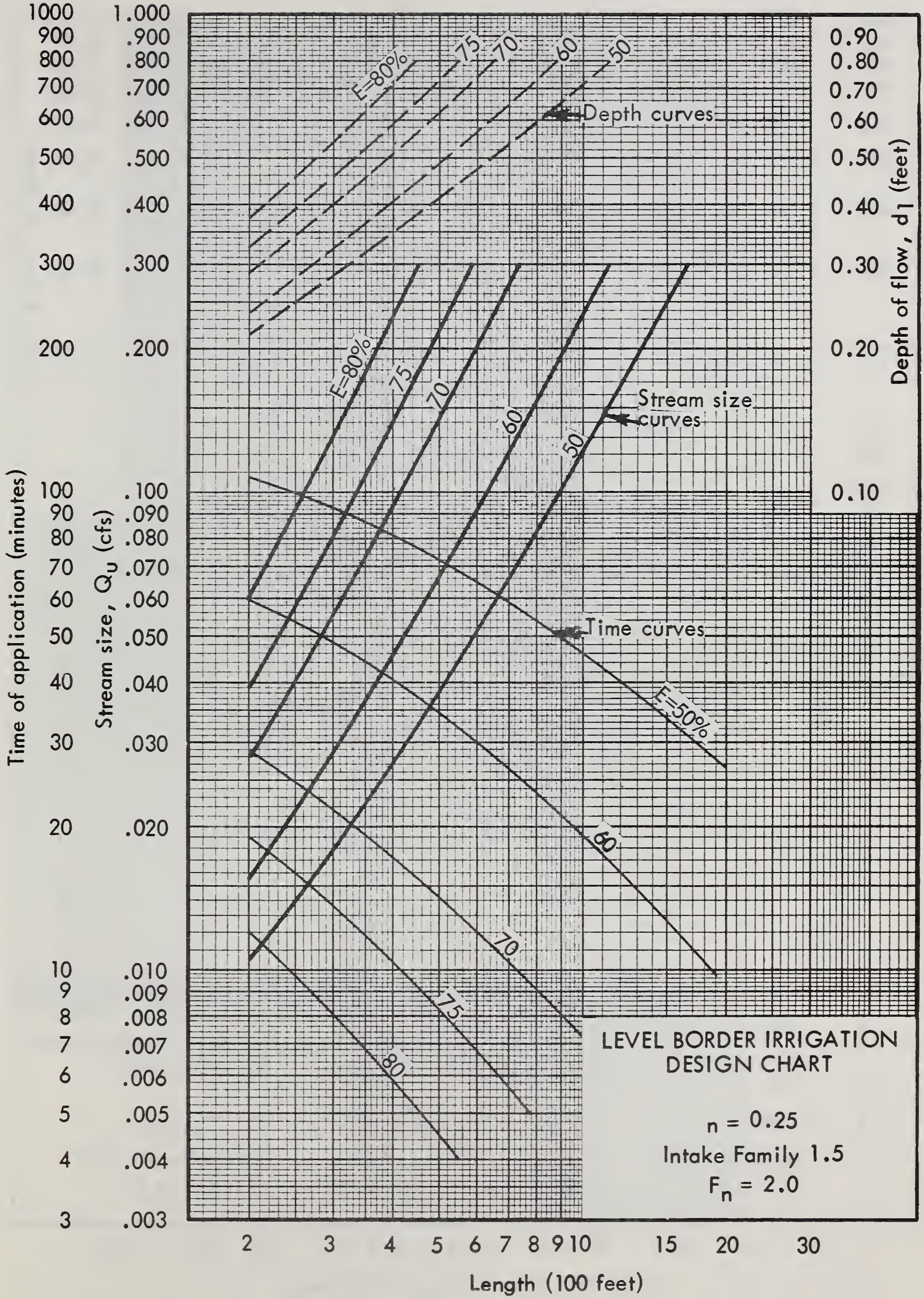


Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=95%
90
85
80
75
70
60
50
Depth curves
Stream size curves
E=95%
90
85
80
75
70
60
50
E=50%
Time curves
60
70
75
80
85
90
95
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
$F_n = 3.0$

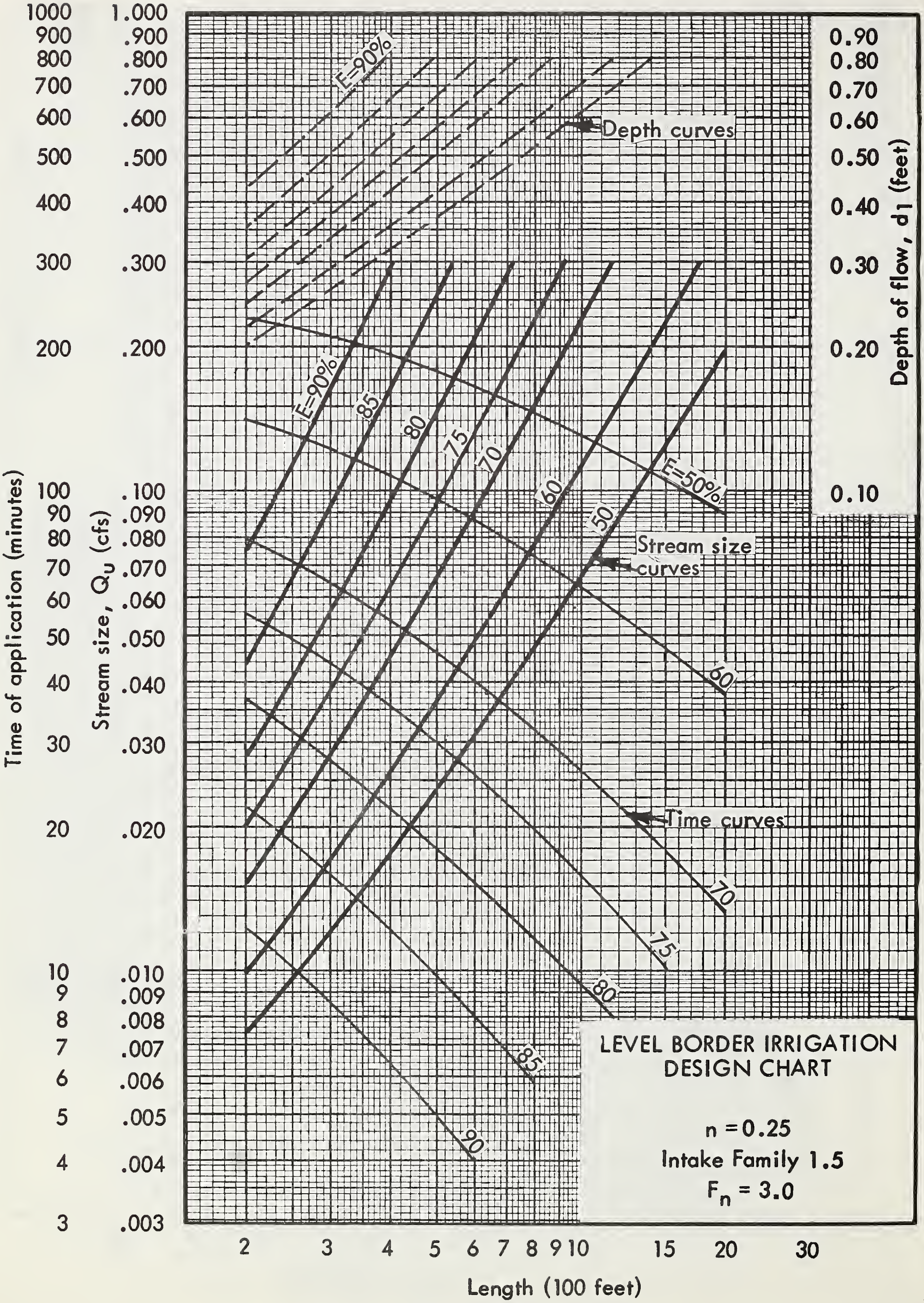


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=95%
90
85
80
75
70
60
50
E=50%
Depth curves
Time curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
F_n = 4.0

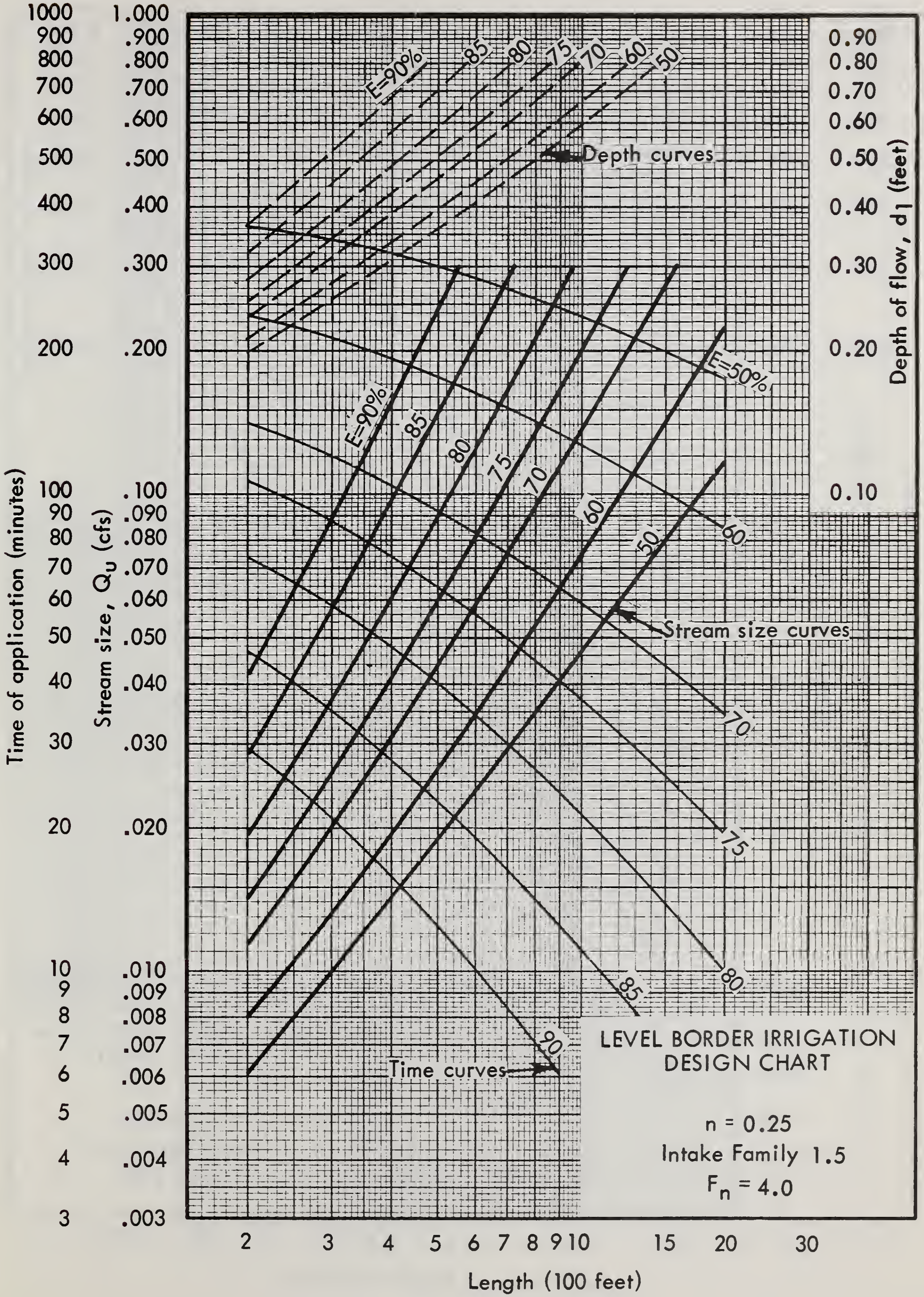

Time curves
E=95%
90
85
80
75
70
60
50
E=50%
Depth curves
60
70
75
80
85
90
95
E=95%
90
85
80
75
70
60
50
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
Fn = 5.0
Time of application (minutes)
Stream size, Qu (cfs)
Depth of flow, d1 (feet)
Length (100 feet)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30

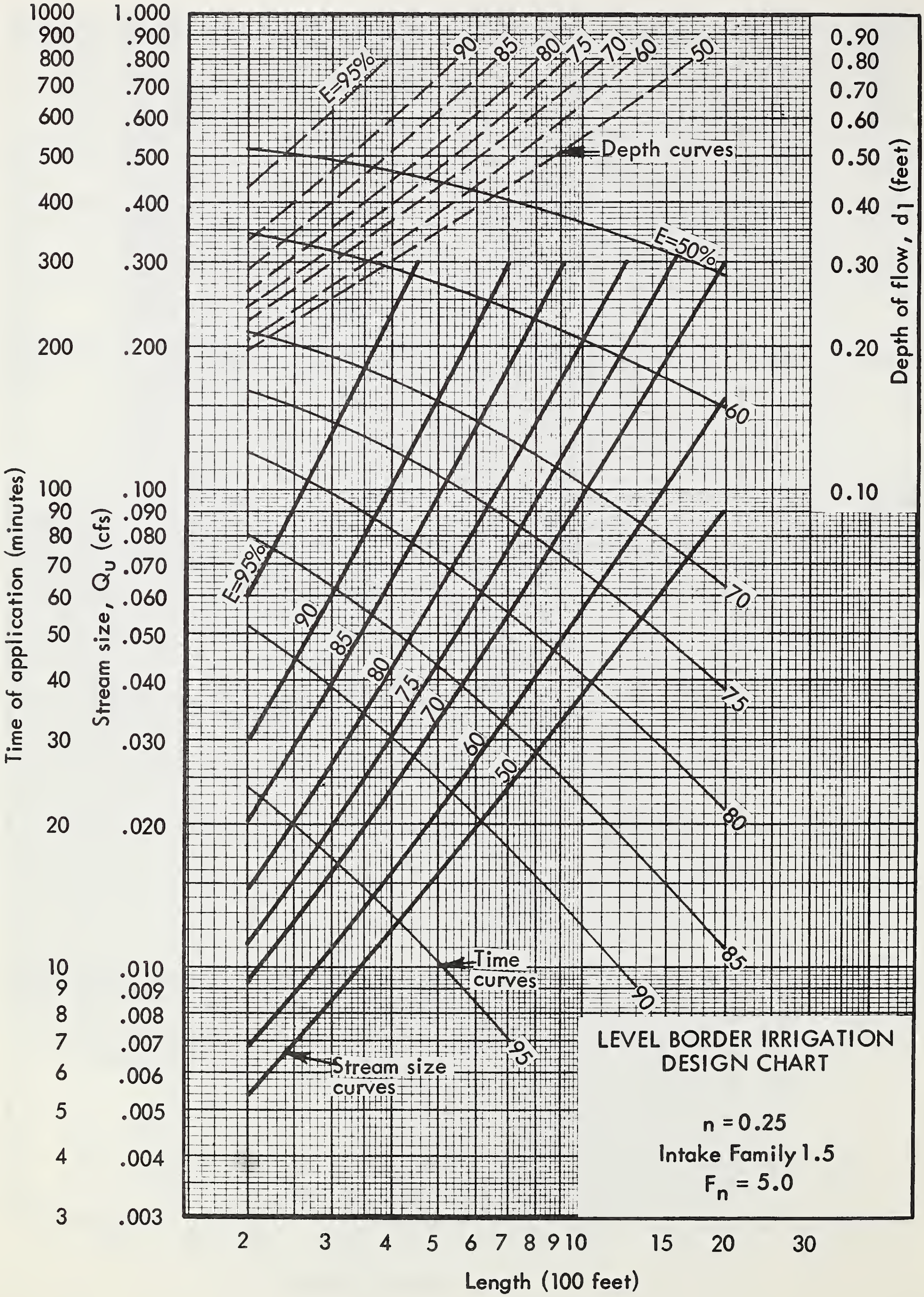


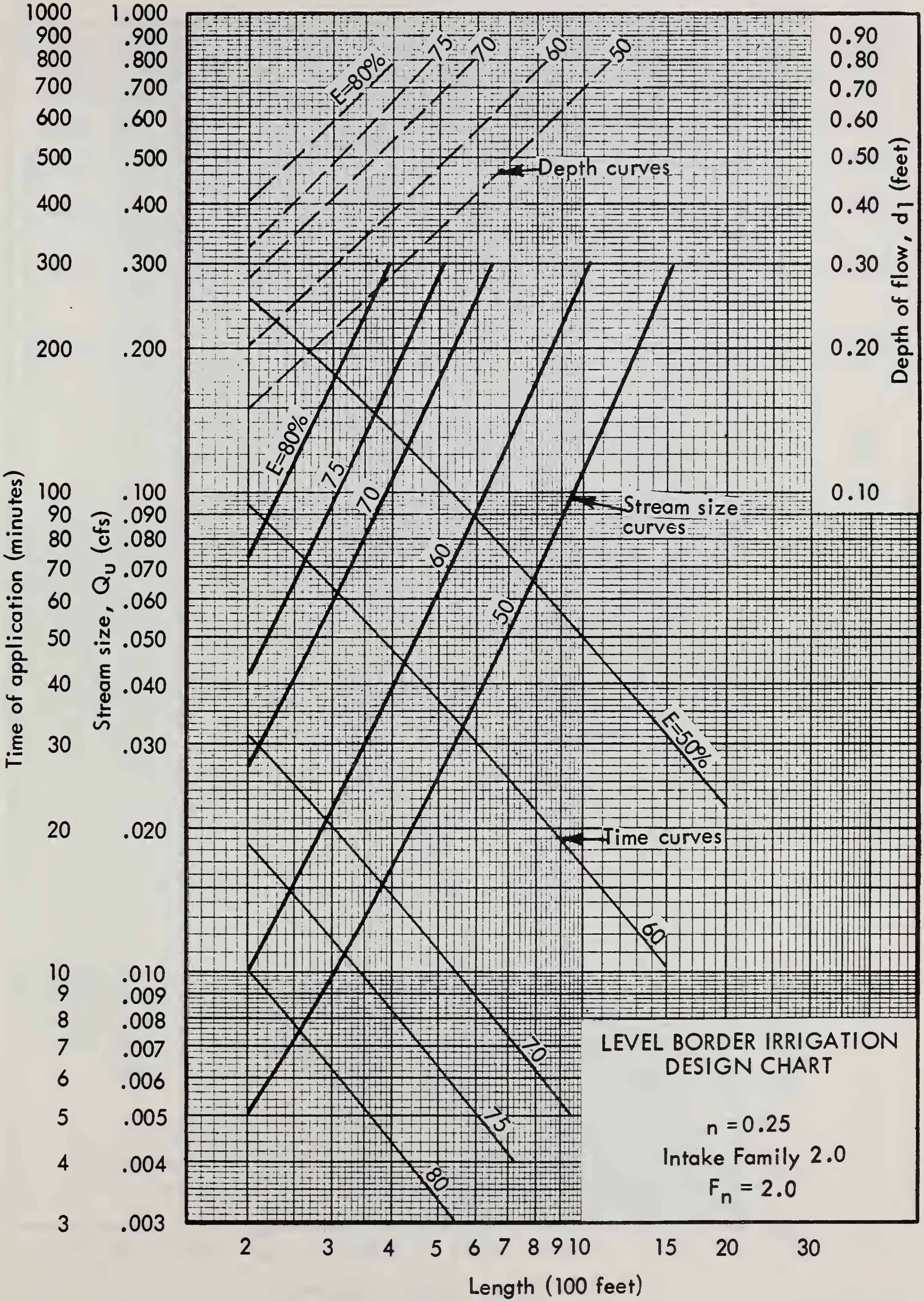
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
Time of application (minutes)
Stream size, Q_u (cfs)
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
Depth of flow, d_1 (feet)
E=80% 75 70 60 50
Depth curves
Stream size curves
Time curves
E=50% 60 70 75 80
2 3 4 5 6 7 8 9 10 15 20 30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.5
F_n = 2.0



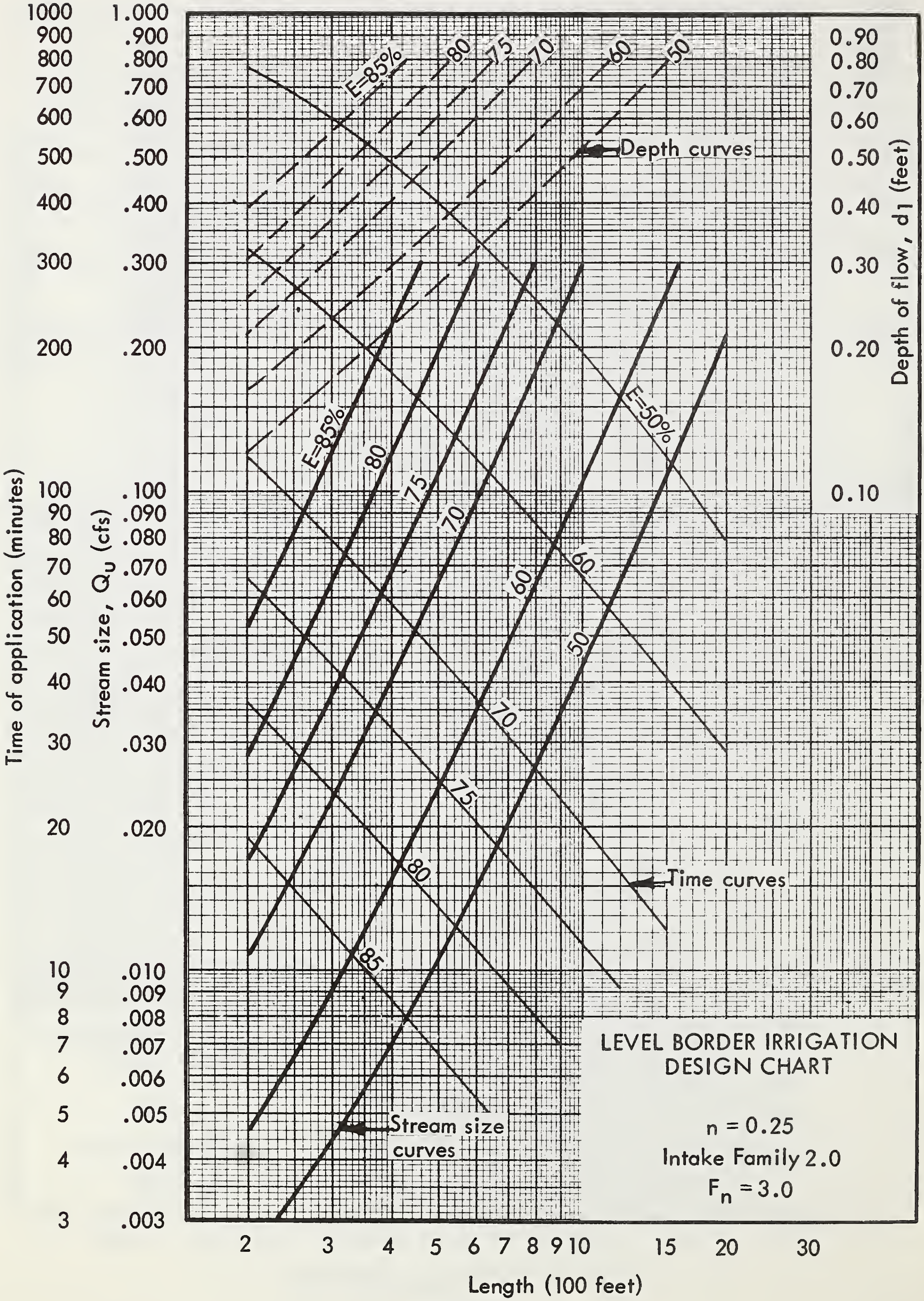
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Time of application (minutes)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Stream size, Qu (cfs)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Depth of flow, d1 (feet)
E=90%
Depth curves
E=90%
85
80
75
70
60
50
E=50%
Stream size curves
60
Time curves
70
75
80
85
90
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.5
Fn = 3.0


LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.5
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=90%
85
80
75
70
60
50
E=50%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30

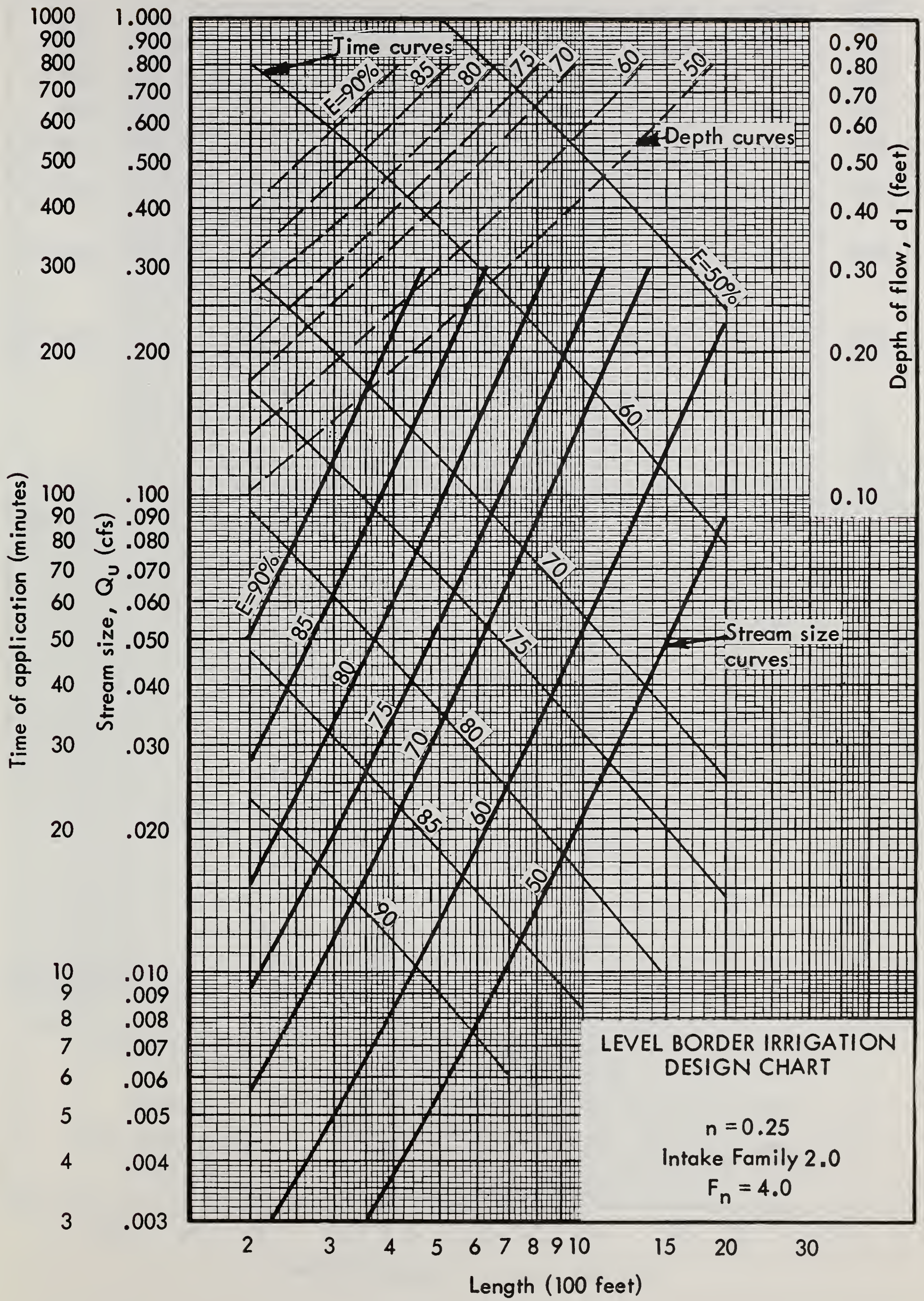

Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=95%
90
85
80
75
70
60
50
Depth curves
E=50%
60
70
75
80
85
90
95
Time curves
Stream size curves
LEVEL BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 1.5
F_n = 5.0
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)

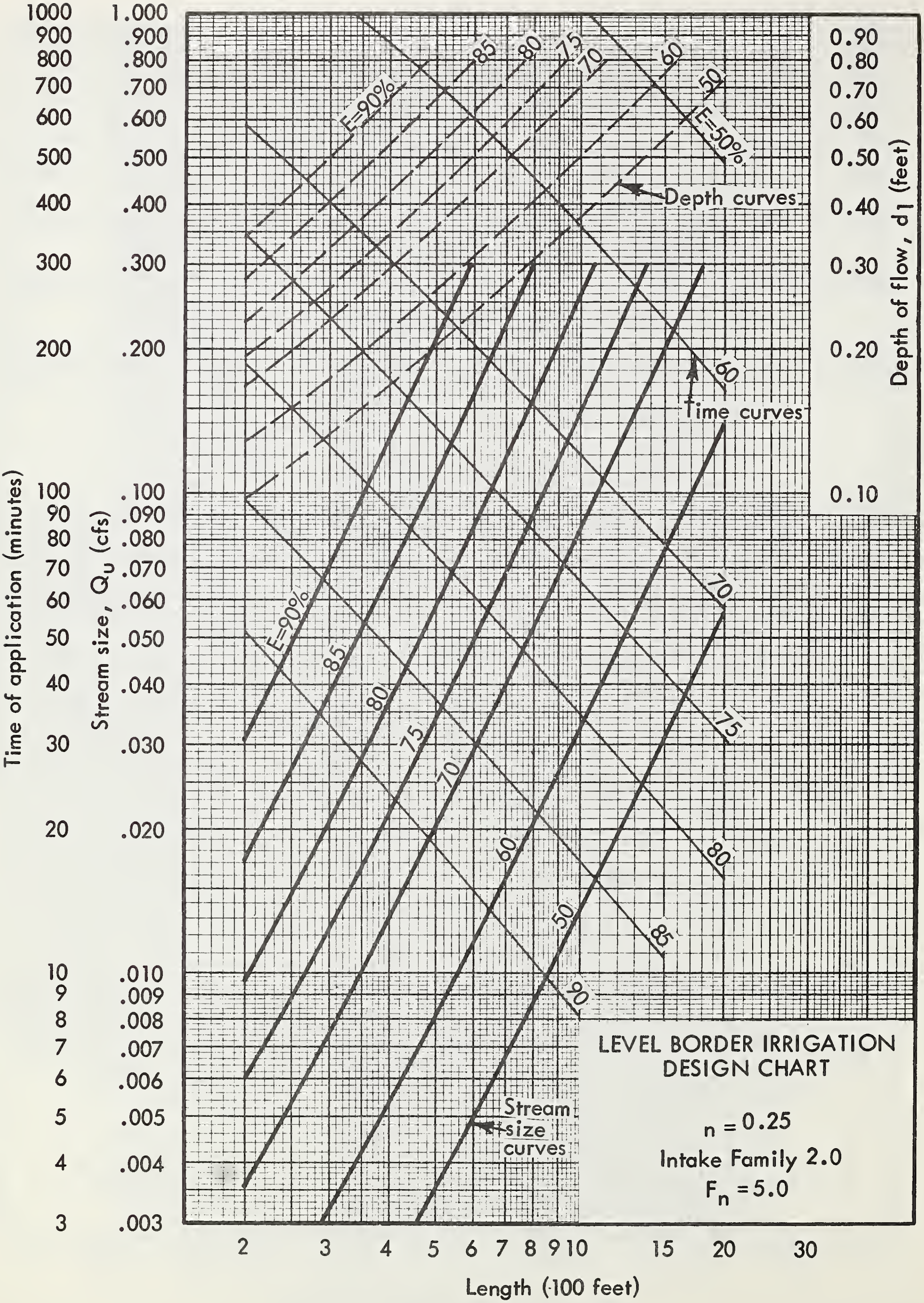


Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=80%
75
70
60
50
Depth curves
E=80%
75
70
60
50
Stream size curves
E=50%
60
70
75
80
Time curves
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 2.0

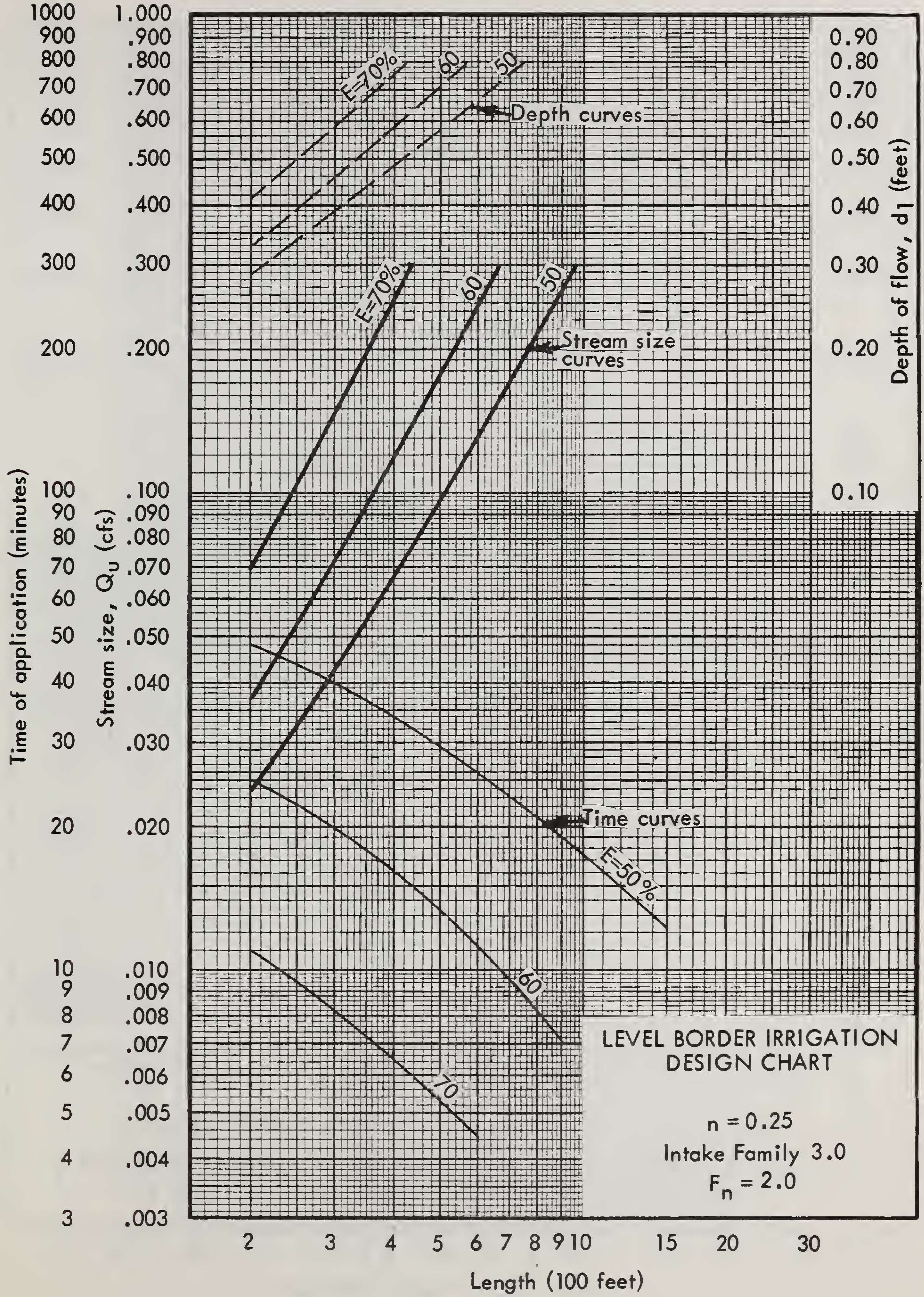


Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=85%
80
75
70
60
50
Depth curves
E=85%
80
75
70
60
50
E=50%
60
70
75
80
85
Time curves
Stream size curves
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 3.0
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)

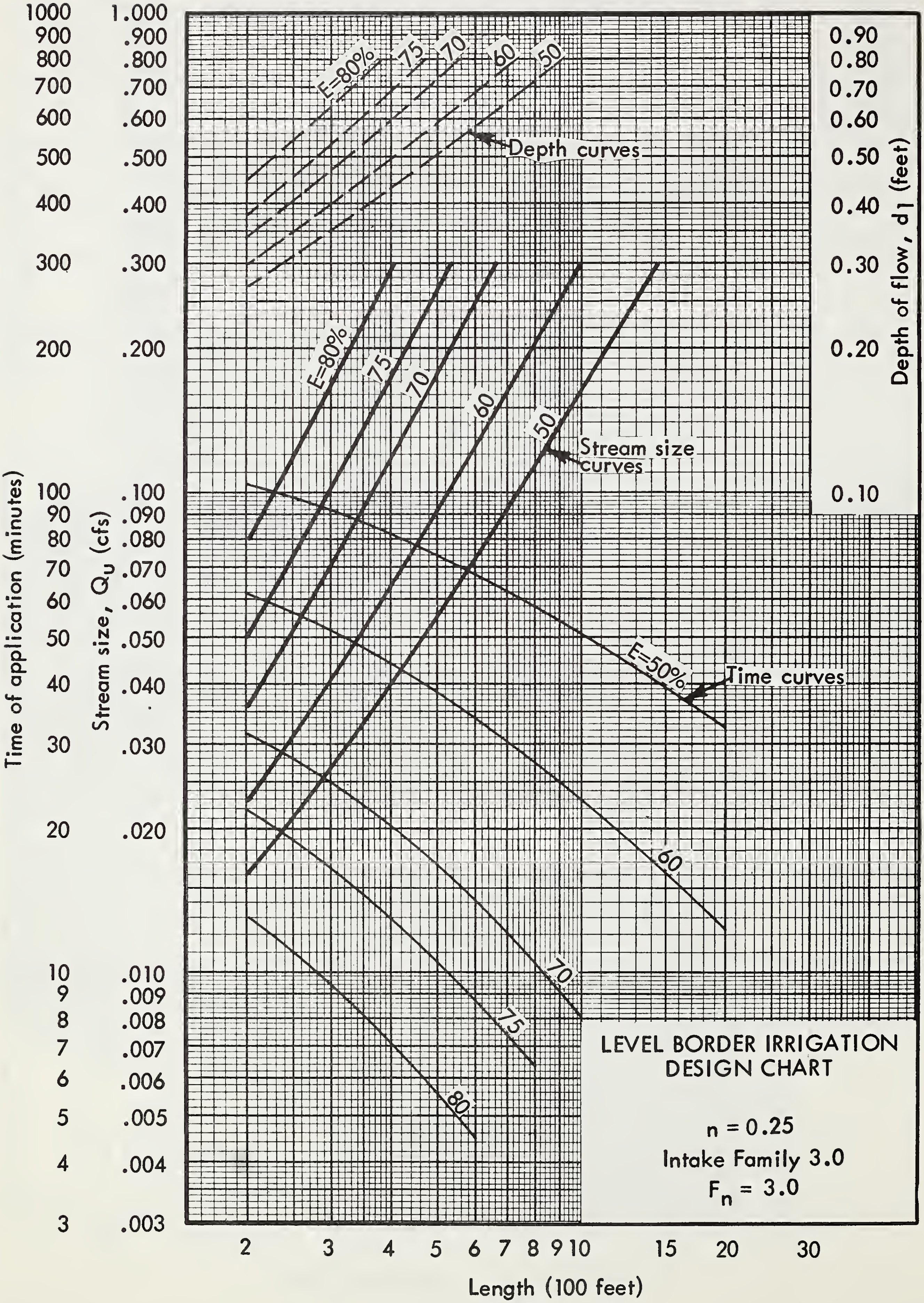

Time curves
Depth curves
Stream size curves
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 4.0



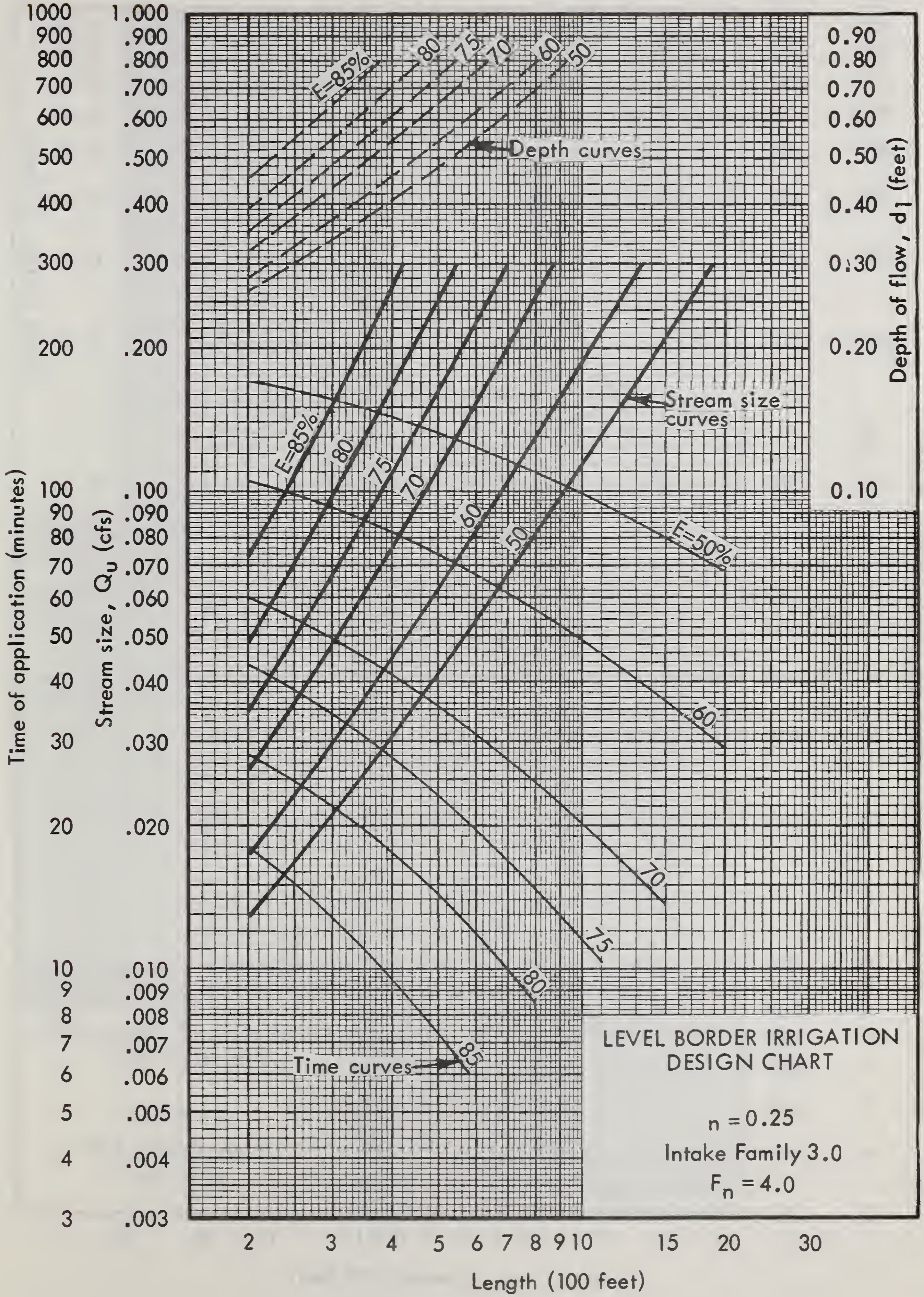
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=90%
E=50%
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30



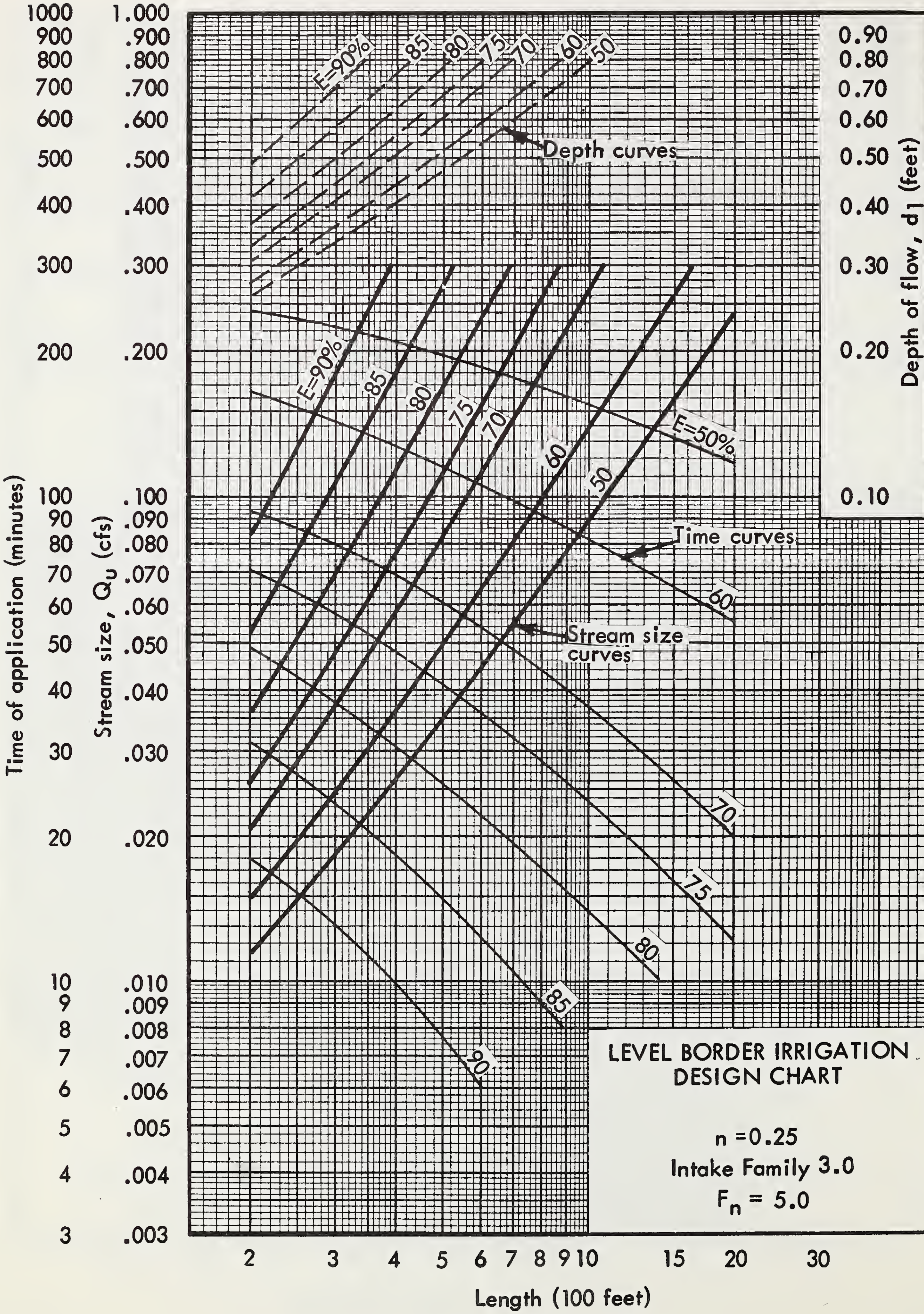
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=70%
60
50
Depth curves
Stream size curves
Time curves
E=50%
70
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 3.0
F_n = 2.0



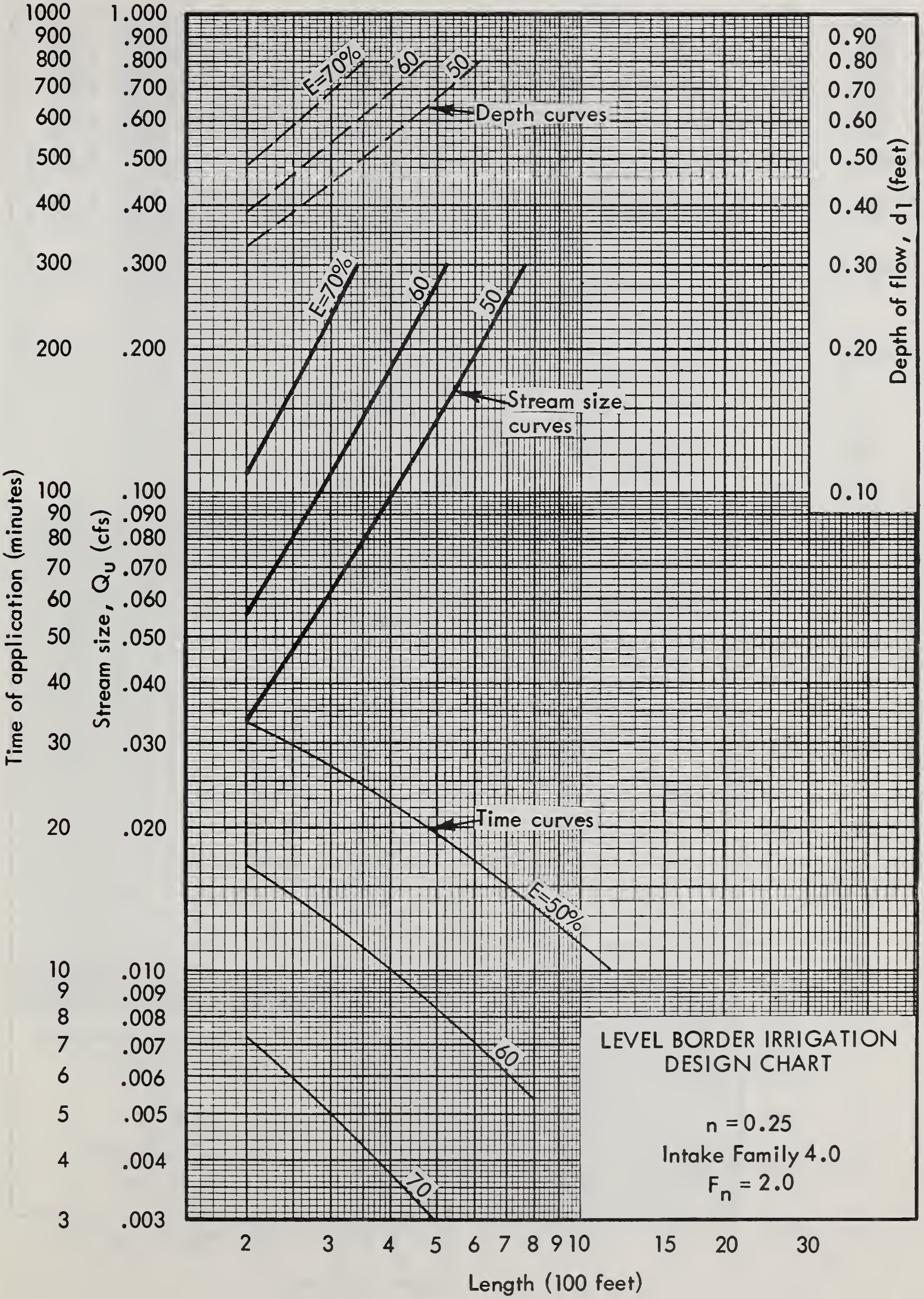
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
E=80%
75
70
60
50
Depth curves
Stream size curves
E=50%
Time curves
80
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 3.0
F_n = 3.0

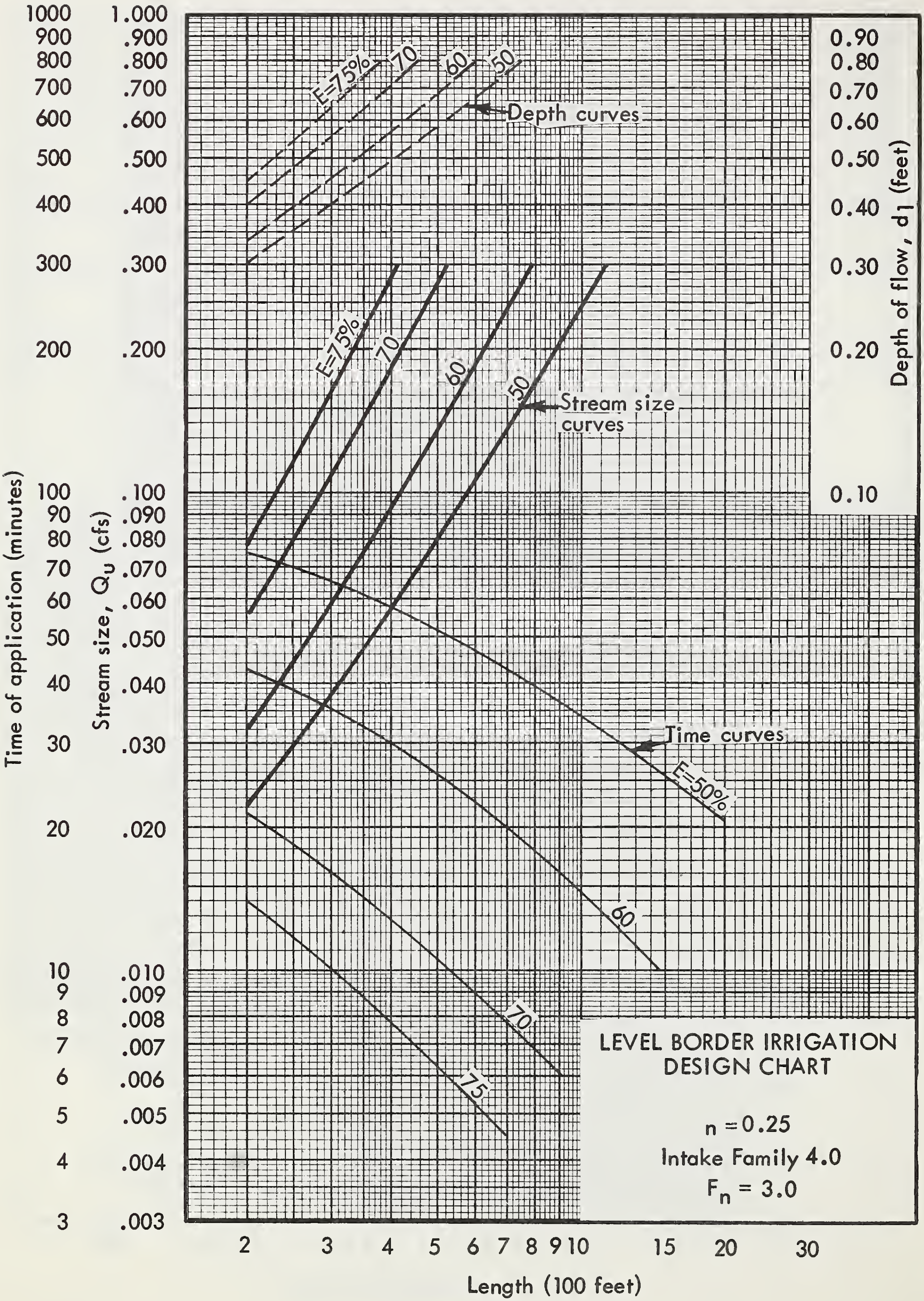


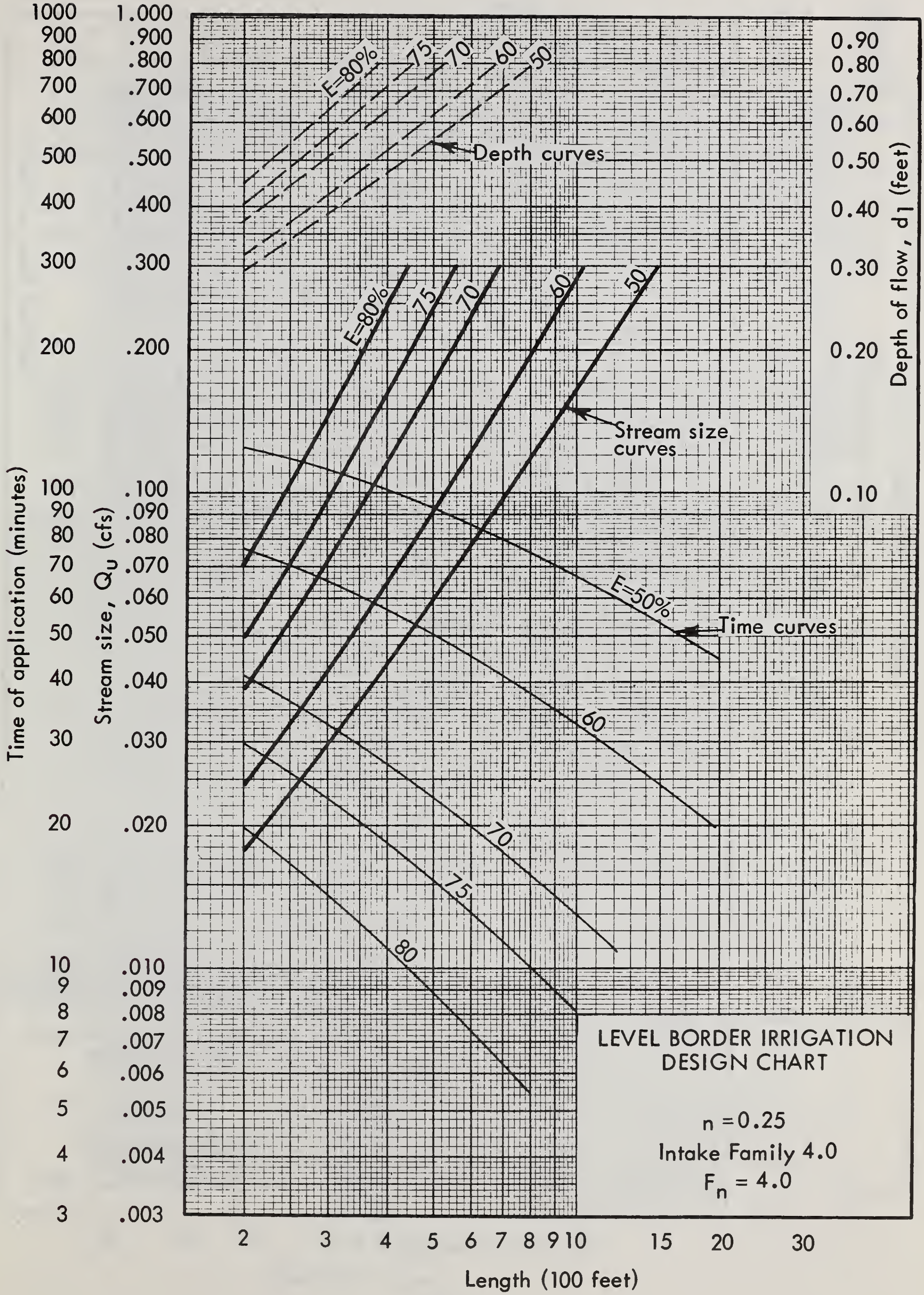
Time of application (minutes)
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3
Stream size, Q_u (cfs)
1.000 .900 .800 .700 .600 .500 .400 .300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003
Depth of flow, d_1 (feet)
0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10
E=85% 80 75 70 60 50
Depth curves
Stream size curves
E=85% 80 75 70 60 50
E=50% 60 70 75 80 85
Time curves
2 3 4 5 6 7 8 9 10 15 20 30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
$n = 0.25$
Intake Family 3.0
$F_n = 4.0$



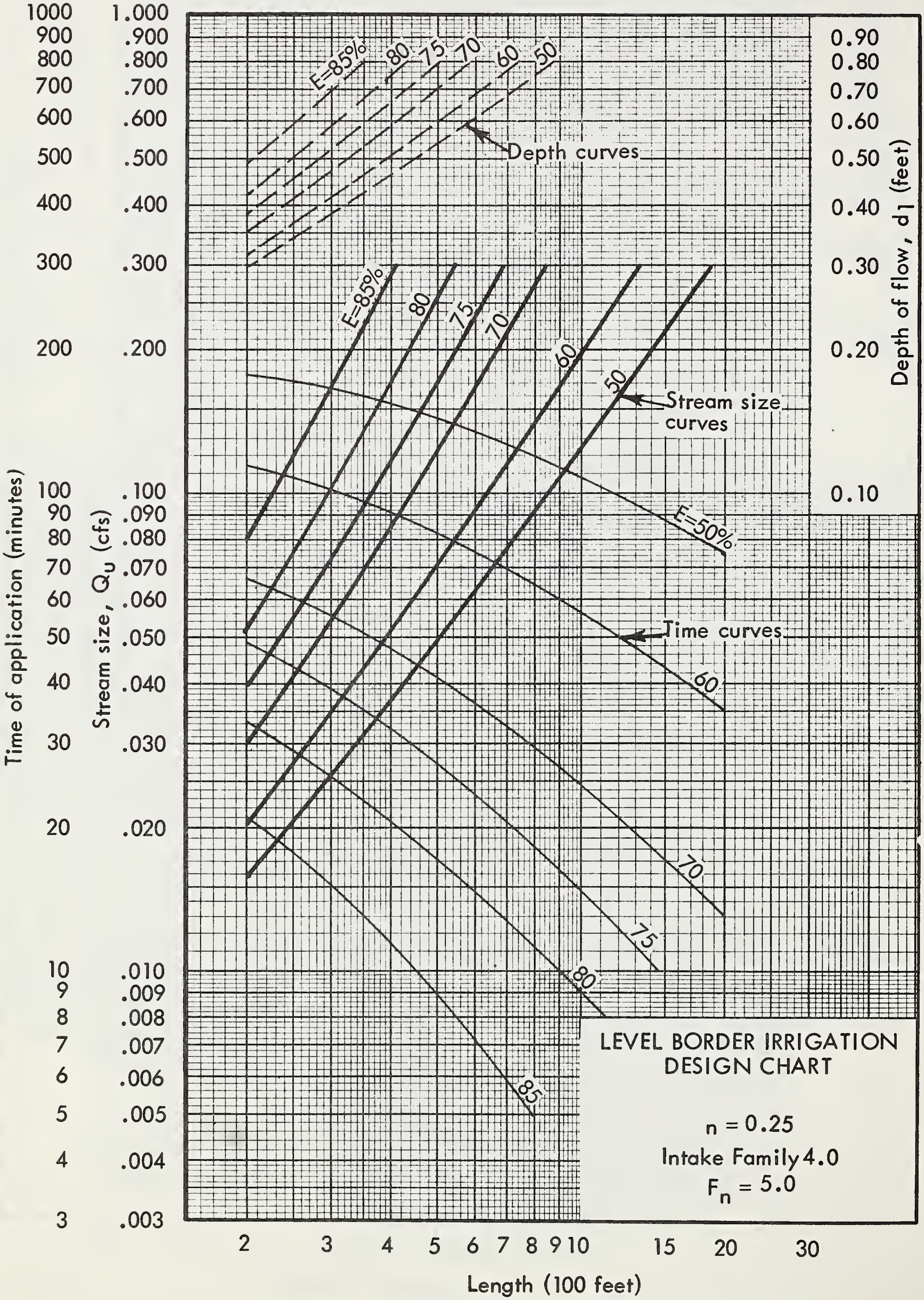
LEVEL BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 3.0
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Time curves
Stream size curves
E=90%
E=50%


Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=70%
60
50
E=50%
70
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 2.0

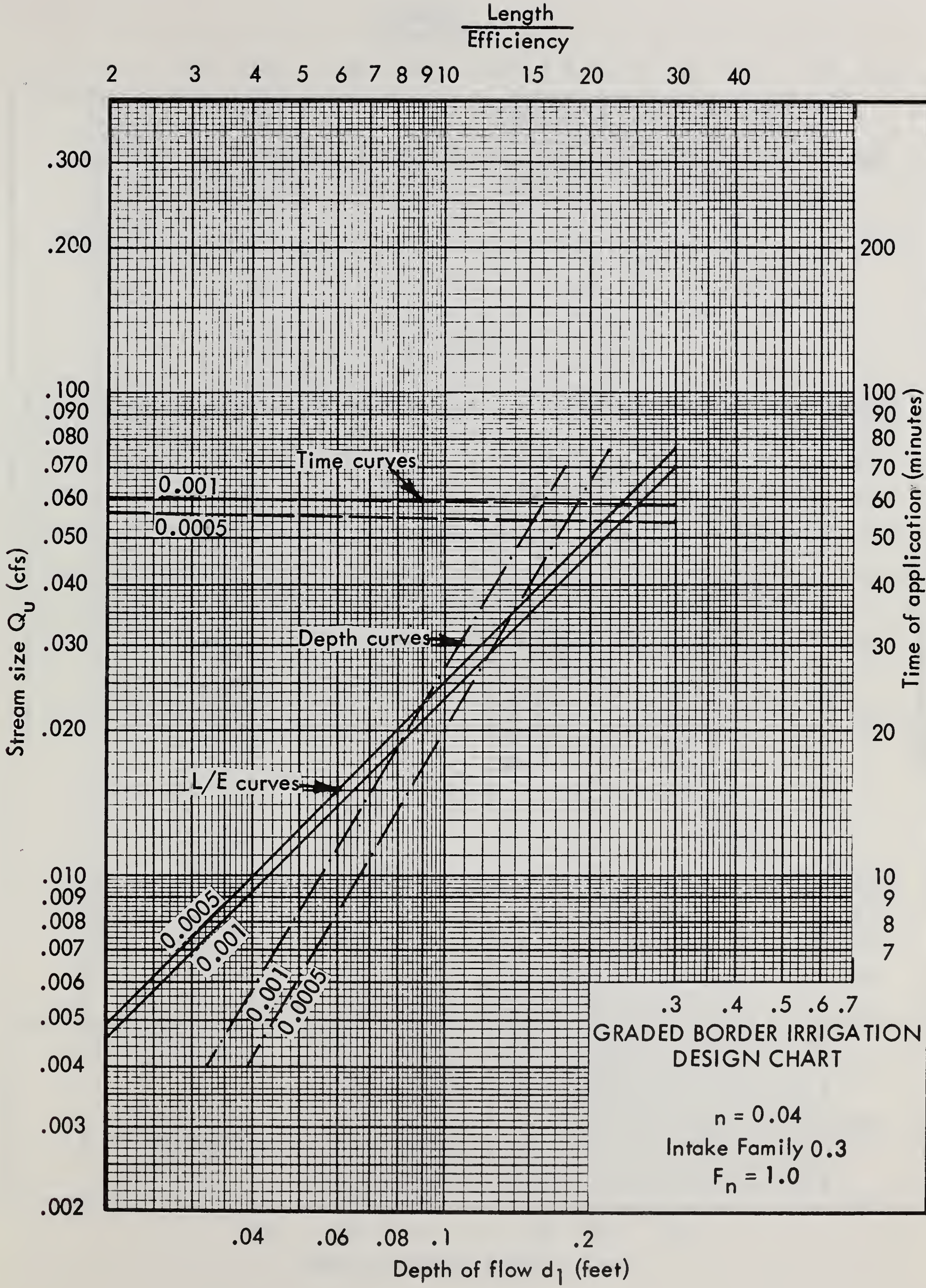

Time of application (minutes)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
Stream size, Q_u (cfs)
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
Depth of flow, d_1 (feet)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
E=75%
70
60
50
Depth curves
E=75%
70
60
50
Stream size curves
Time curves
E=50%
60
70
75
2
3
4
5
6
7
8
9
10
15
20
30
Length (100 feet)
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 3.0



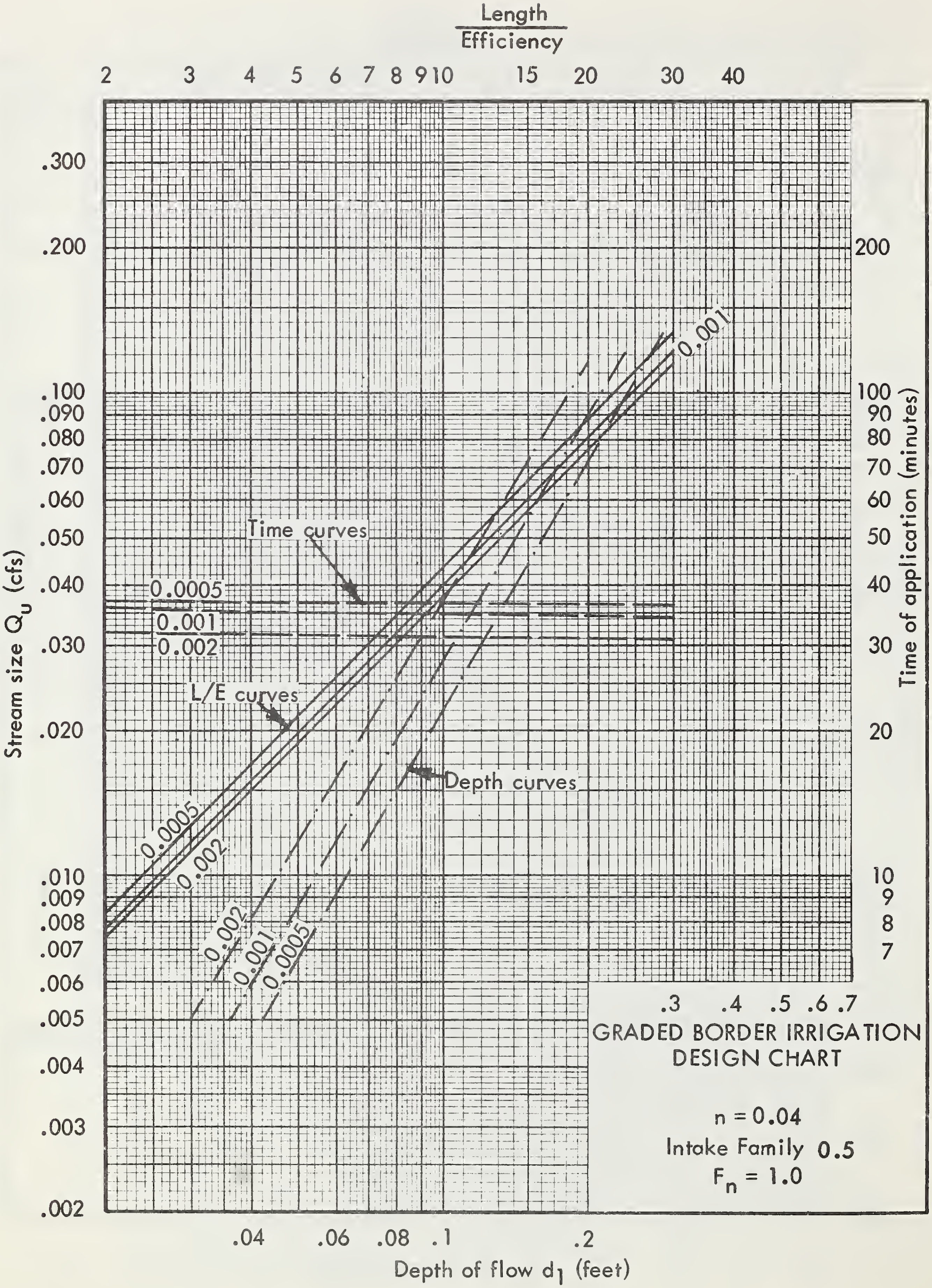
LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 4.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=80%
75
70
60
50
E=50%
80
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
1.000
.900
.800
.700
.600
.500
.400
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
2
3
4
5
6
7
8
9
10
15
20
30



LEVEL BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 5.0
Time of application (minutes)
Stream size, Q_u (cfs)
Depth of flow, d_1 (feet)
Length (100 feet)
Depth curves
Stream size curves
Time curves
E=85%
80
75
70
60
50
E=50%
85



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time curves
0.001
0.0005
Depth curves
L/E curves
0.0005
0.001
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.3
F_n = 1.0

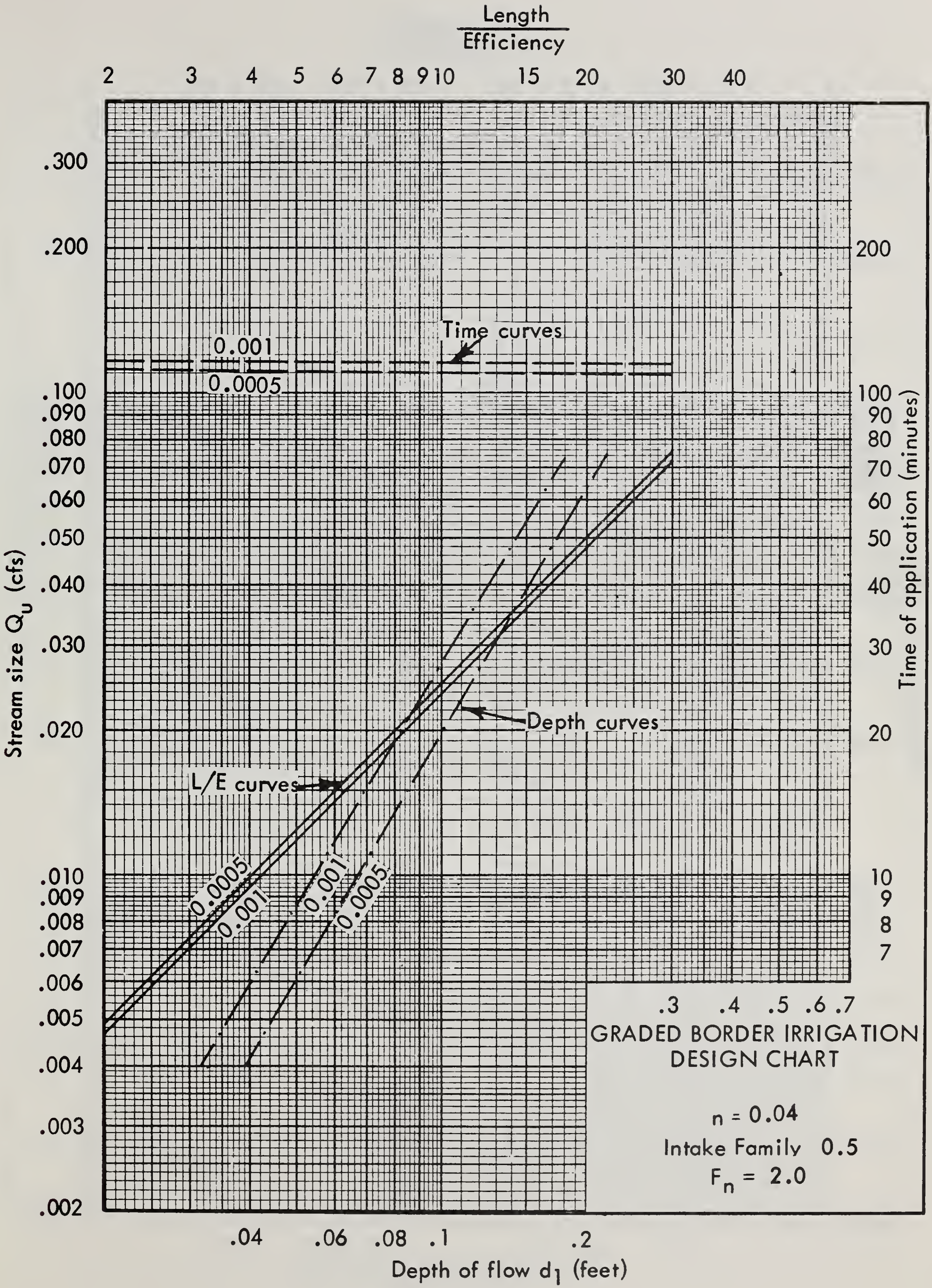


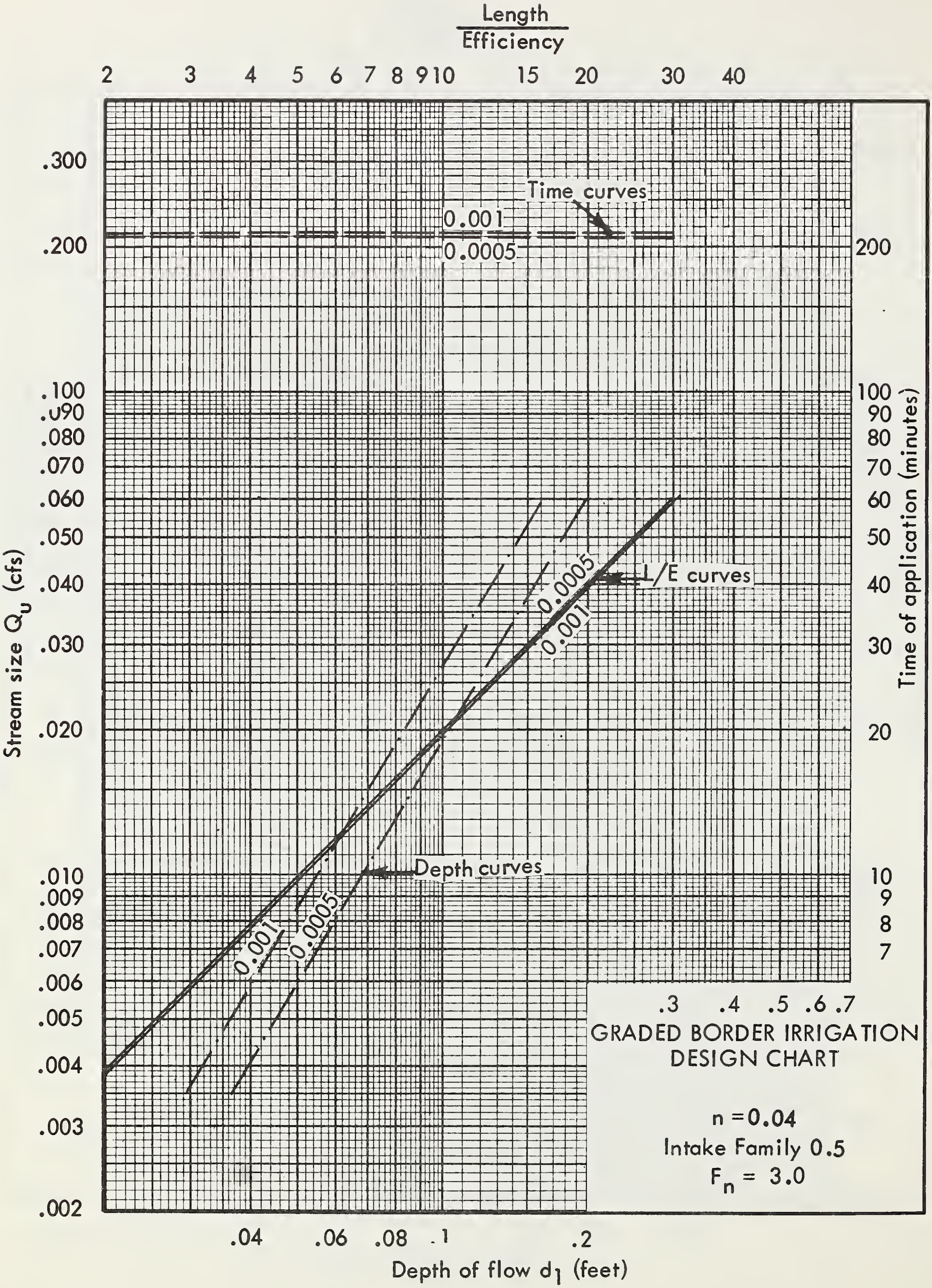
GRADED BORDER IRRIGATION DESIGN CHART

n = 0.04

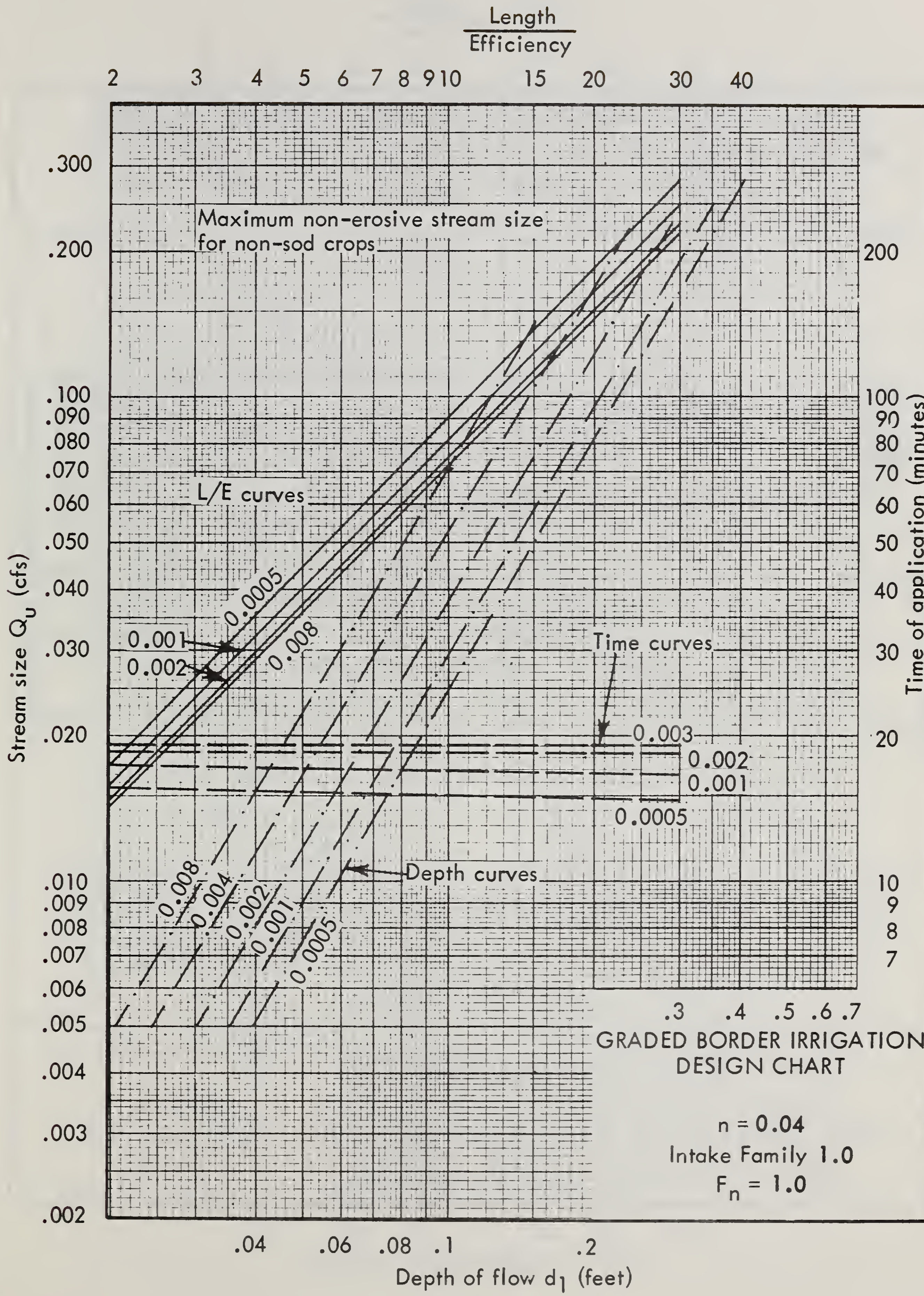
Intake Family 0.5

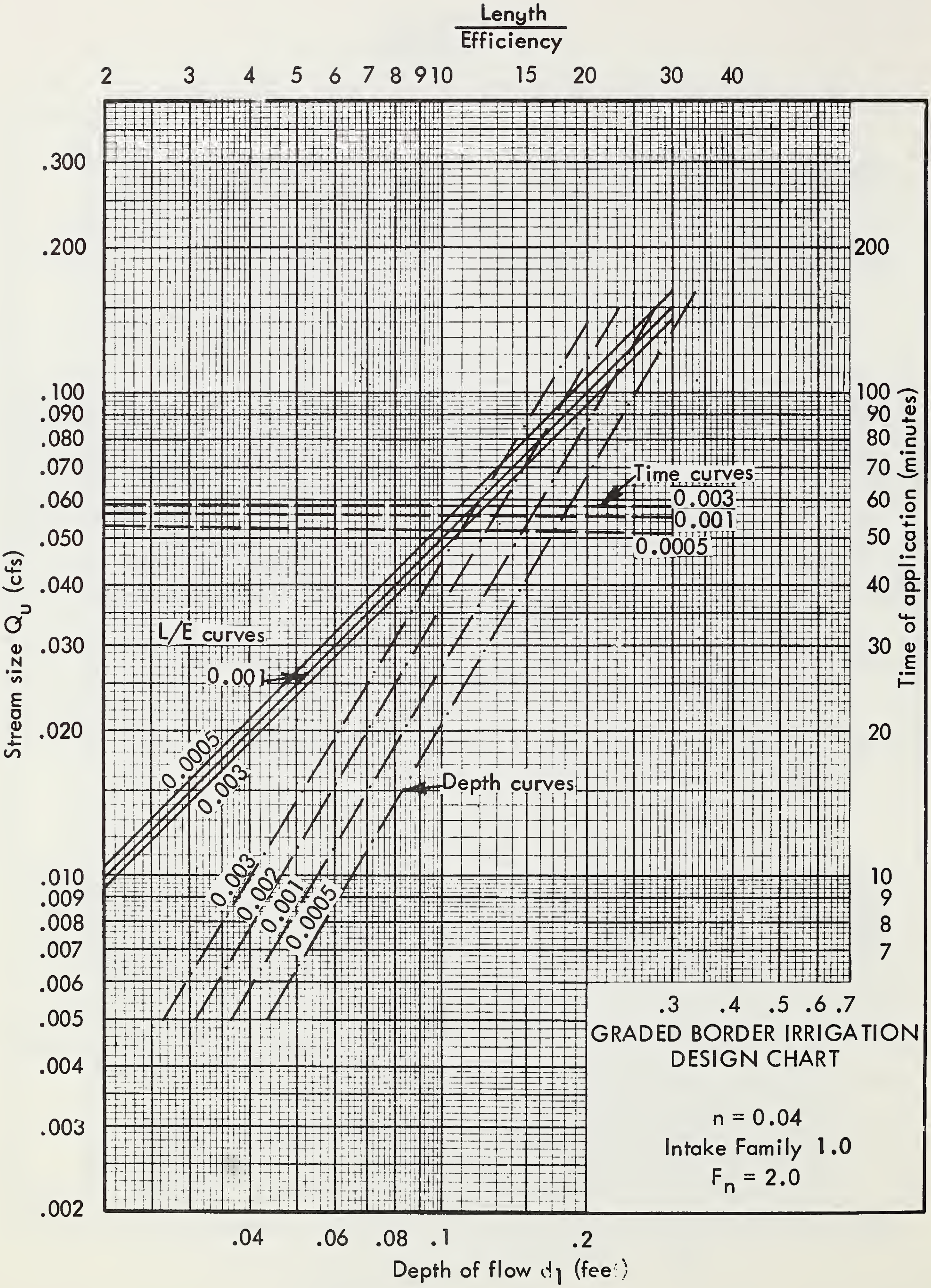
$F_n = 1.0$

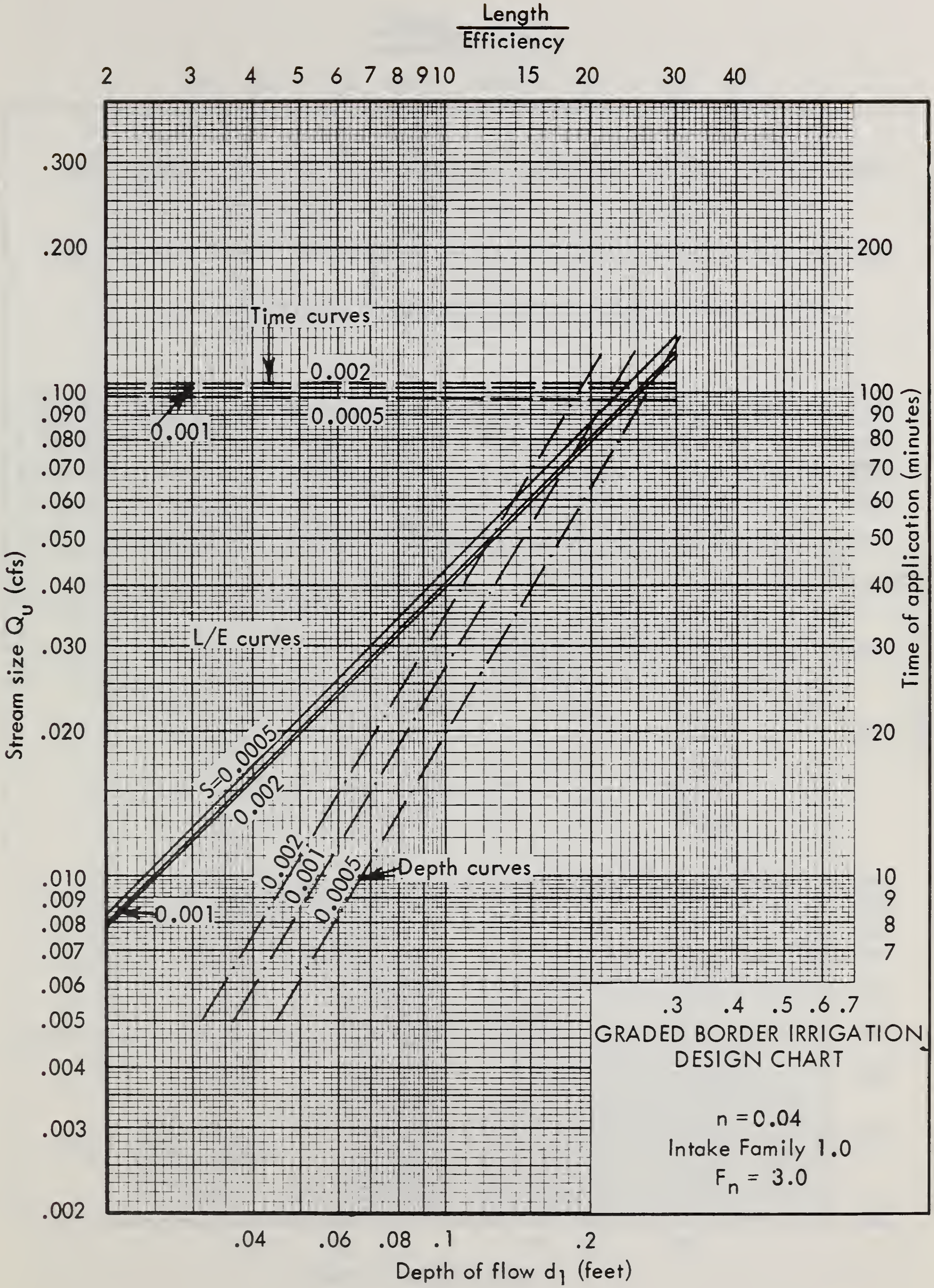

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
Time curves
0.001
0.0005
Depth curves
L/E curves
0.0005
0.001
0.001
0.0005
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 2.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)



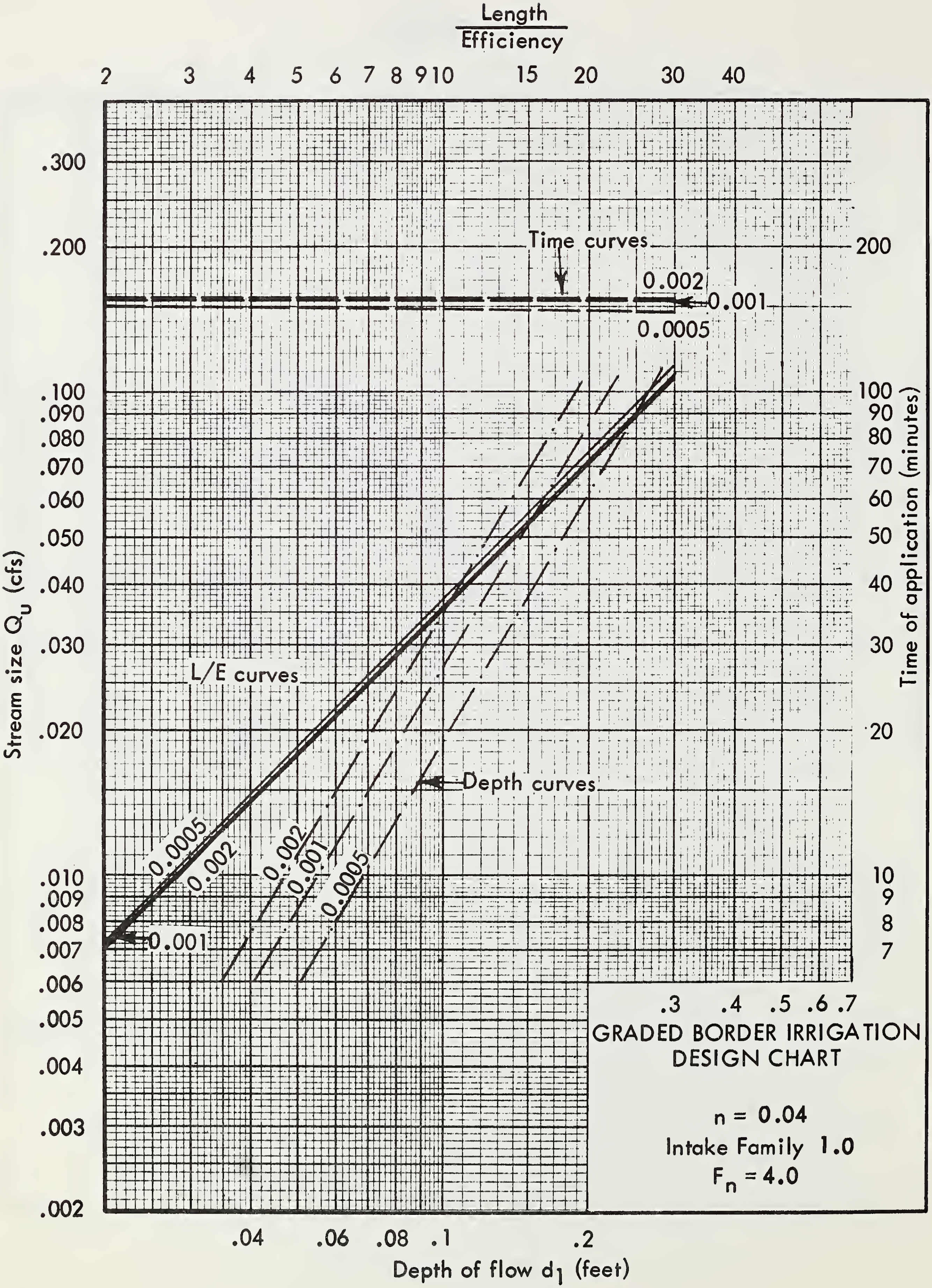
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
Time curves
0.001
0.0005
200
100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
0.0005
0.001
L/E curves
Depth curves
0.001
0.0005
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 0.5
F_n = 3.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
0.0005
0.001
0.002
0.008
Time curves
0.003
0.002
0.001
0.0005
Depth curves
0.008
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 1.0

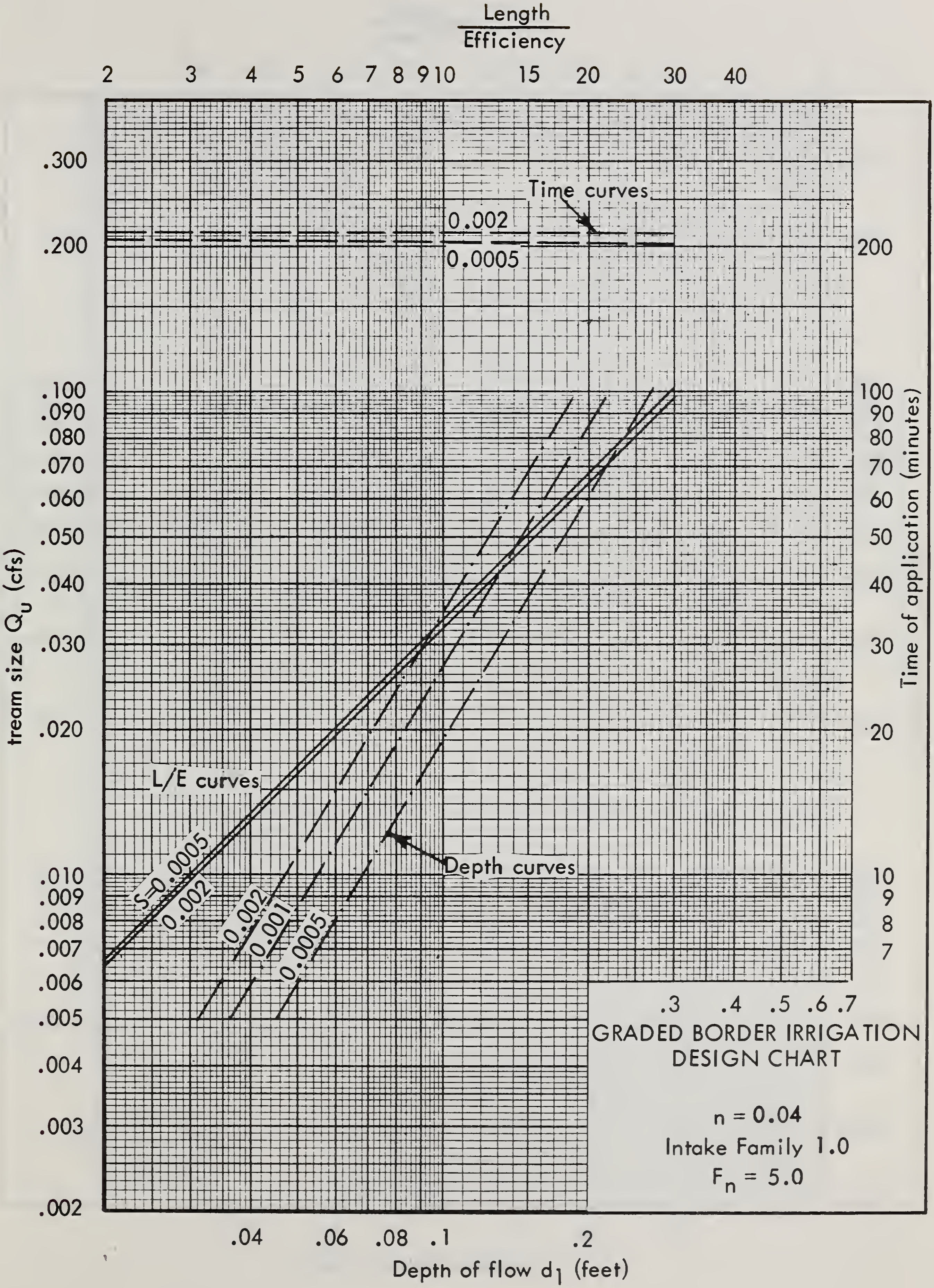

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
Time curves
0.003
0.001
0.0005
L/E curves
0.001
0.0005
0.003
Depth curves
0.003
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 2.0

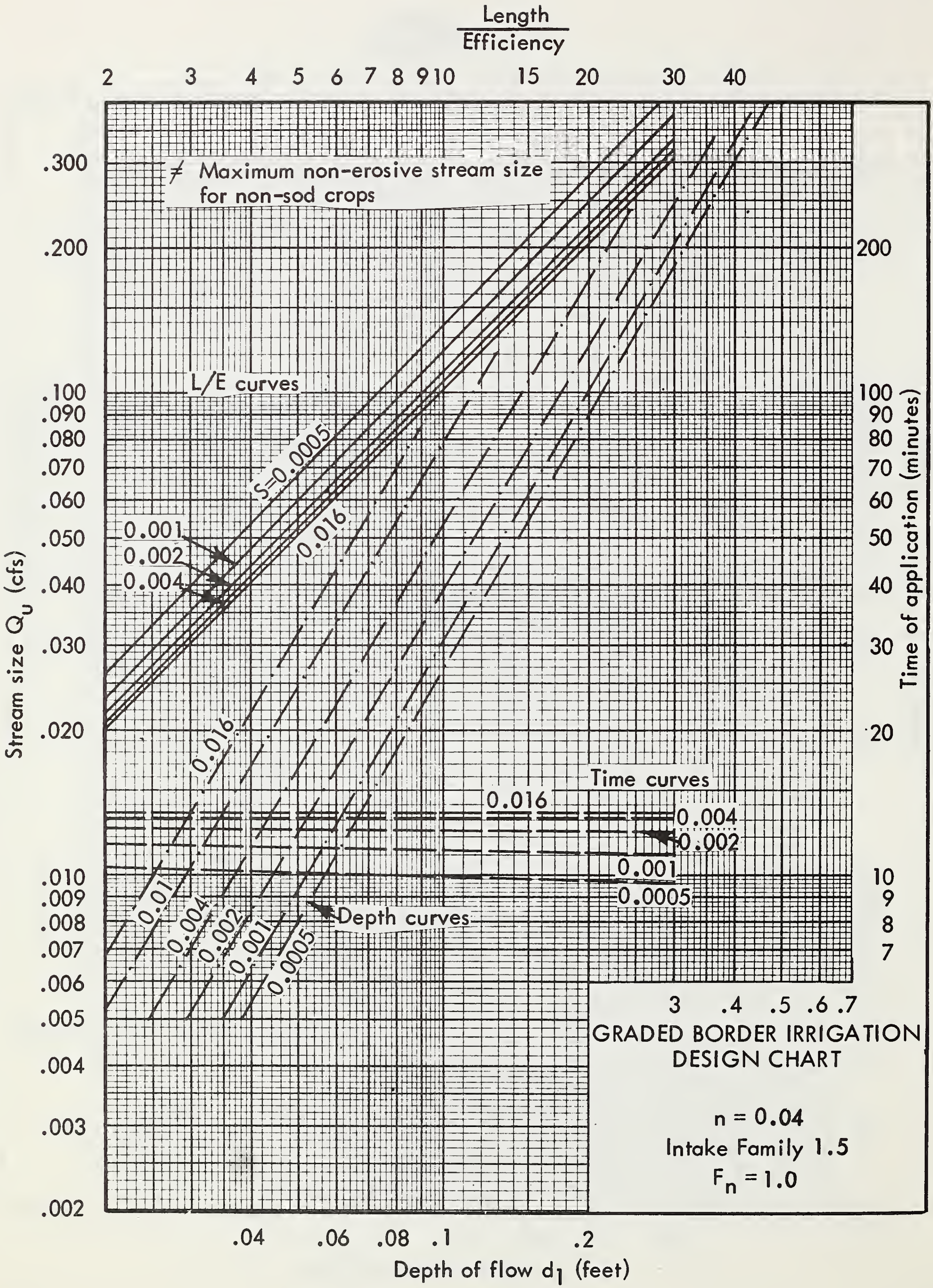


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time curves
0.002
0.0005
0.001
L/E curves
S=0.0005
0.002
0.001
Depth curves
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 3.0

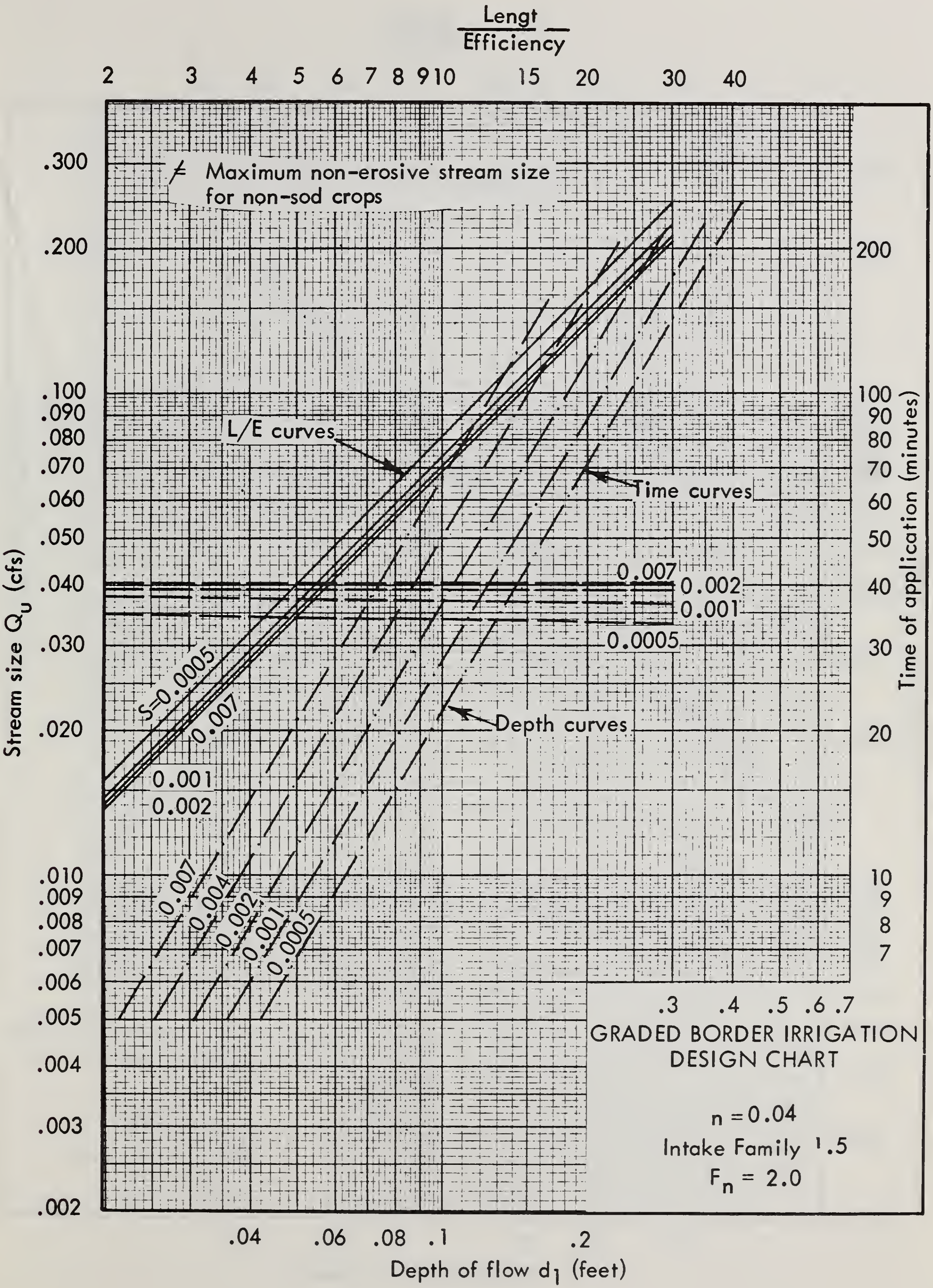


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
Time curves
0.002
0.001
0.0005
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
L/E curves
Depth curves
0.0005
0.002
0.002
0.001
0.0005
0.001
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 4.0

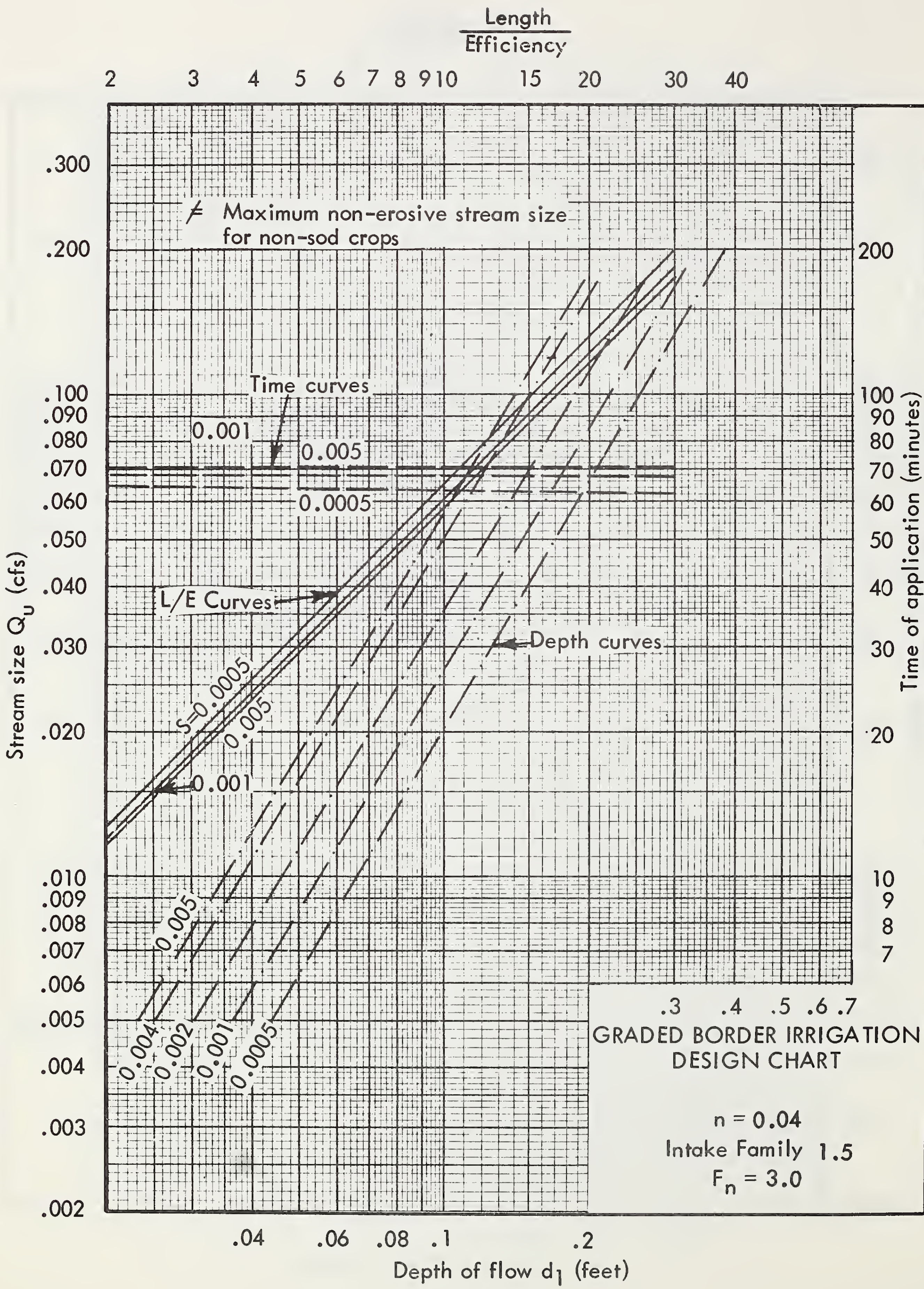

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
tream size Q_u (cfs)
Time curves
0.002
0.0005
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
L/E curves
S=0.0005
0.002
0.002
0.001
0.0005
Depth curves
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.04
Intake Family 1.0
F_n = 5.0



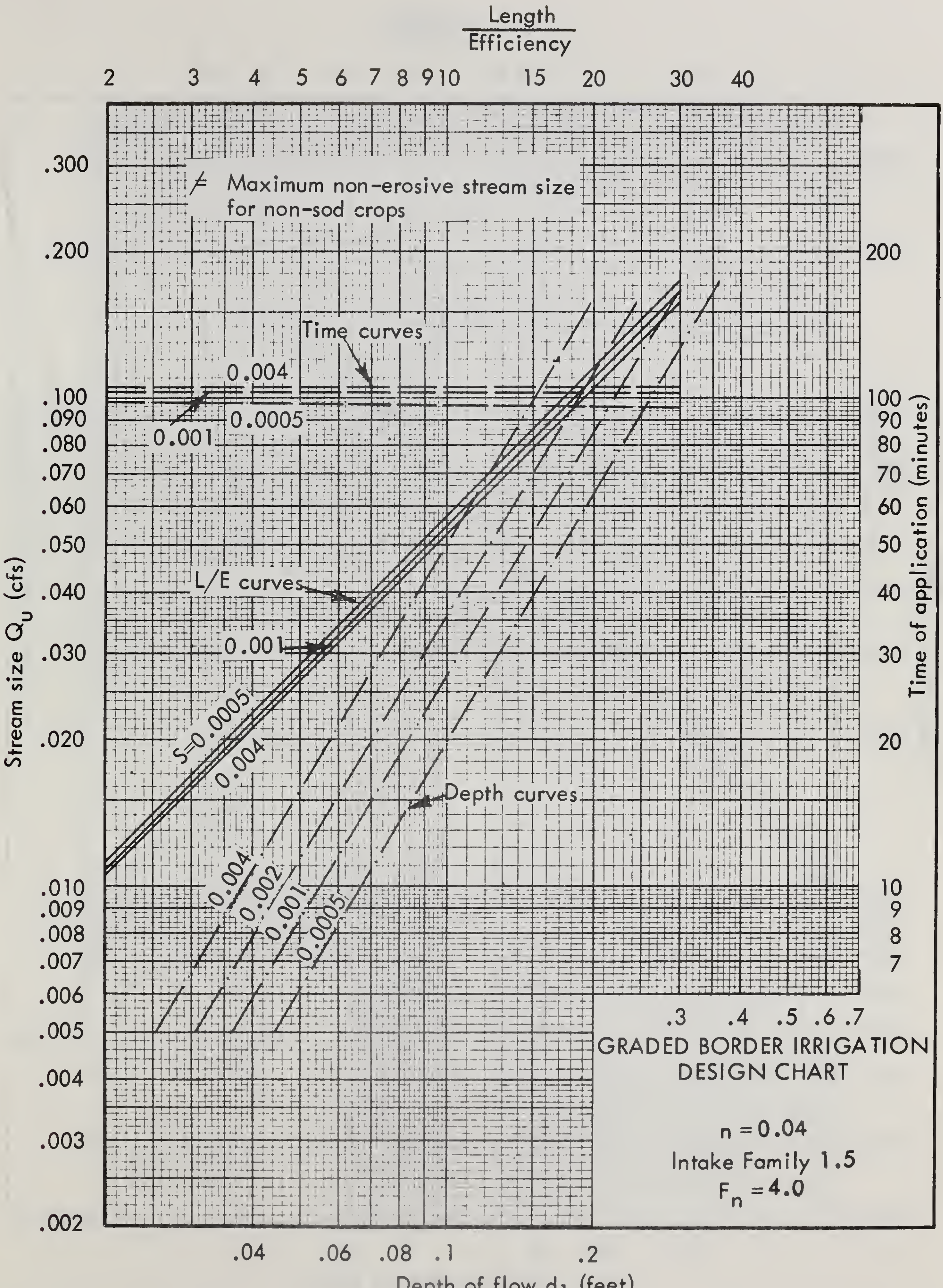
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
≠ Maximum non-erosive stream size for non-sod crops
L/E curves
S=0.0005
0.001
0.002
0.004
0.016
Time curves
0.016
0.004
0.002
0.001
0.0005
Depth curves
0.01
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 1.0



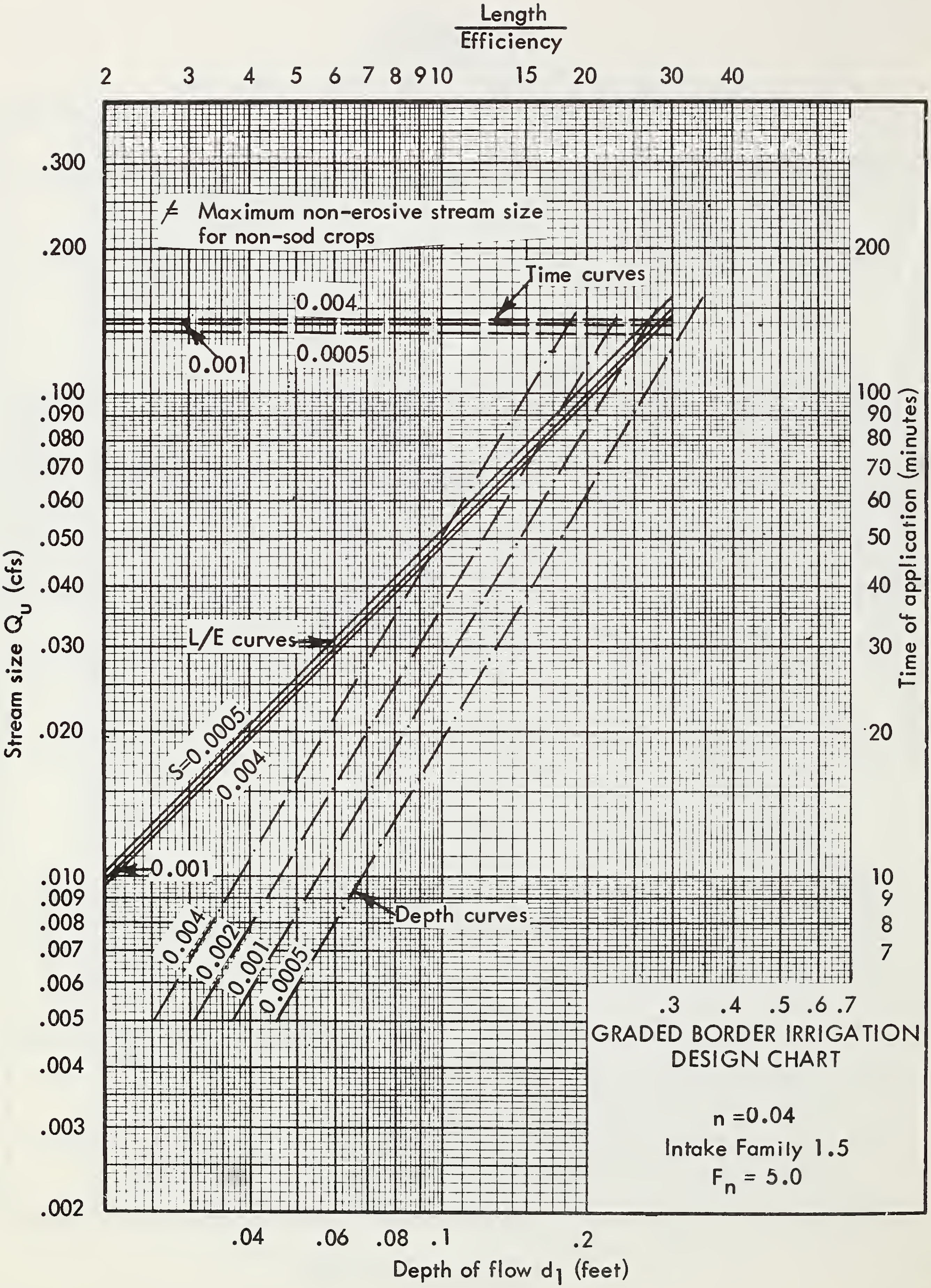
Lengt
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
Time curves
Depth curves
S=0.0005
0.007
0.001
0.002
0.007
0.002
0.001
0.0005
0.007
0.004
0.002
0.001
0.0005
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Stream size Q_u (cfs)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 2.0



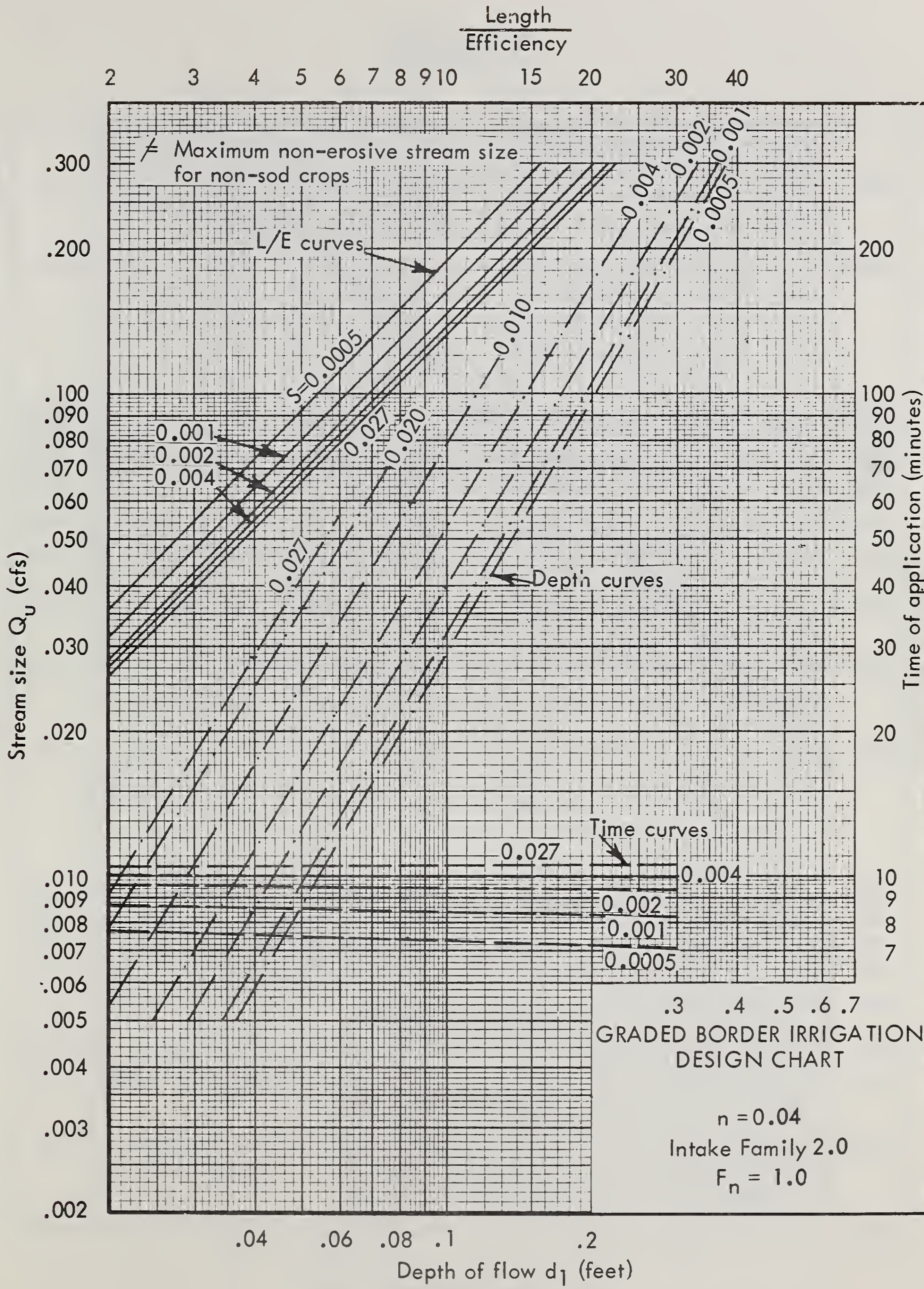
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Time curves
0.001
0.005
0.0005
L/E Curves
S=0.0005
0.005
0.001
Depth curves
0.005
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 3.0

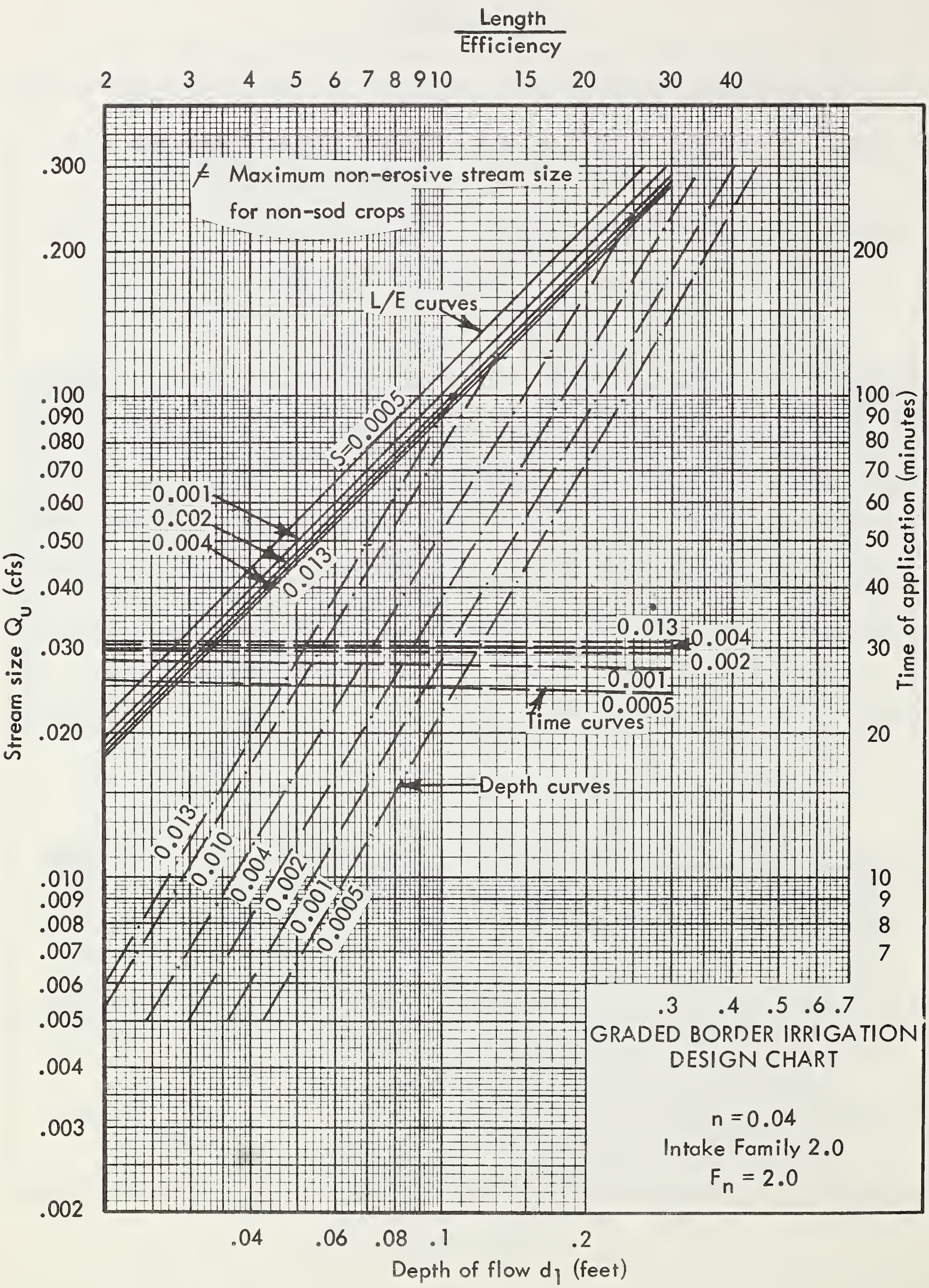


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Time curves
0.004
0.0005
0.001
L/E curves
0.001
S=0.0005
0.004
Depth curves
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 1.5
F_n = 4.0

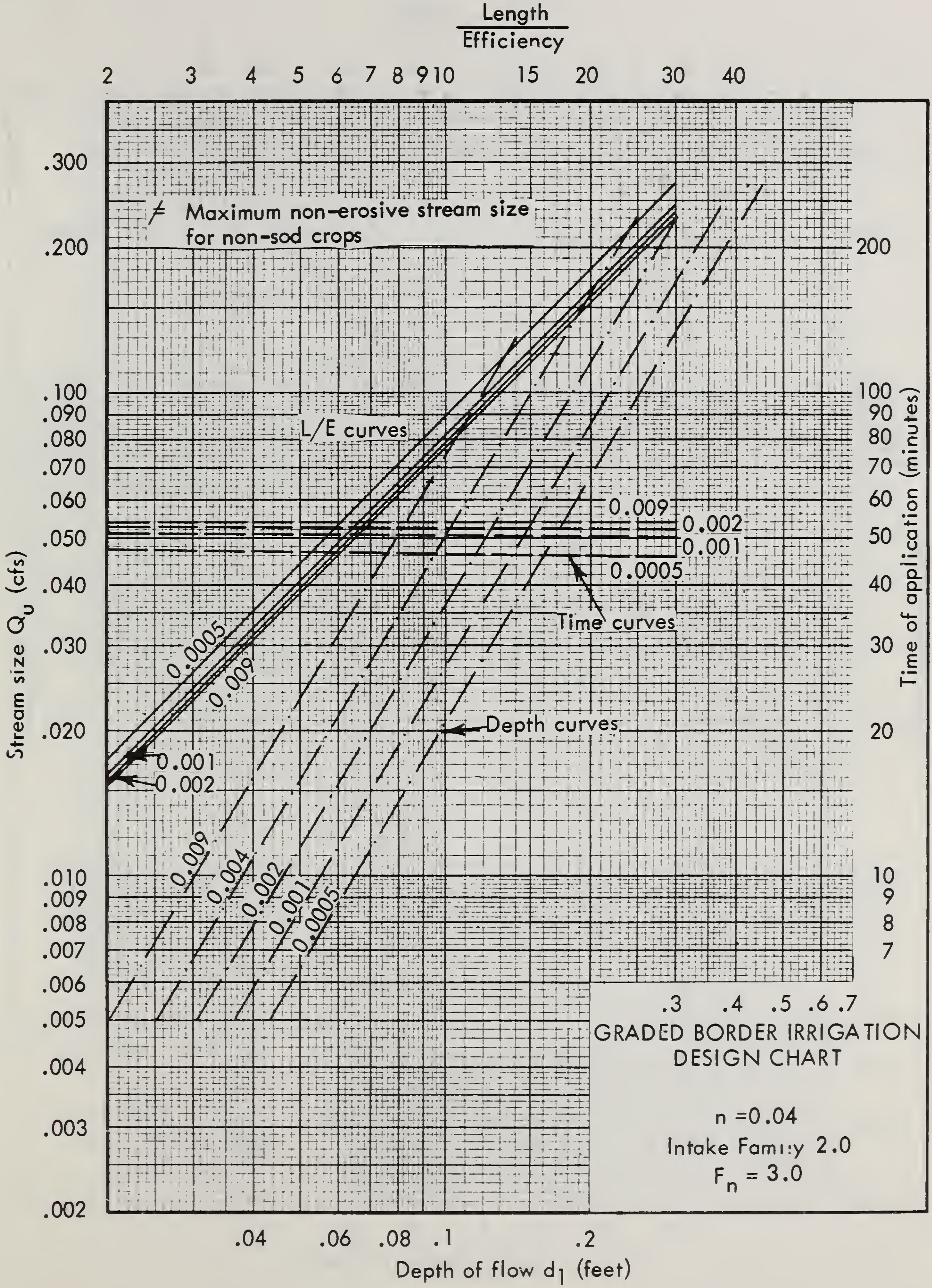


Length
Efficiency
2
3
4
5
6
7
8
9
10
15
20
30
40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
Maximum non-erosive stream size for non-sod crops
Time curves
0.004
0.001
0.0005
L/E curves
S=0.0005
0.004
0.001
Depth curves
0.004
0.002
0.001
0.0005
.3
.4
.5
.6
.7
GRADED BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 1.5
F_n = 5.0
.04
.06
.08
.1
.2
Depth of flow d_1 (feet)


Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
S=0.0005
0.001
0.002
0.004
0.027
0.020
0.010
0.004
0.002
0.001
0.0005
Depth curves
Time curves
0.027
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 1.0



Length
Efficiency
2
3
4
5
6
7
8
9
10
15
20
30
40
Maximum non-erosive stream size for non-sod crops
L/E curves
S=0.0005
0.001
0.002
0.004
0.013
0.013
0.004
0.002
0.001
0.0005
Time curves
Depth curves
0.013
0.010
0.004
0.002
0.001
0.0005
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04
.06
.08
.1
.2
.3
.4
.5
.6
.7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 2.0

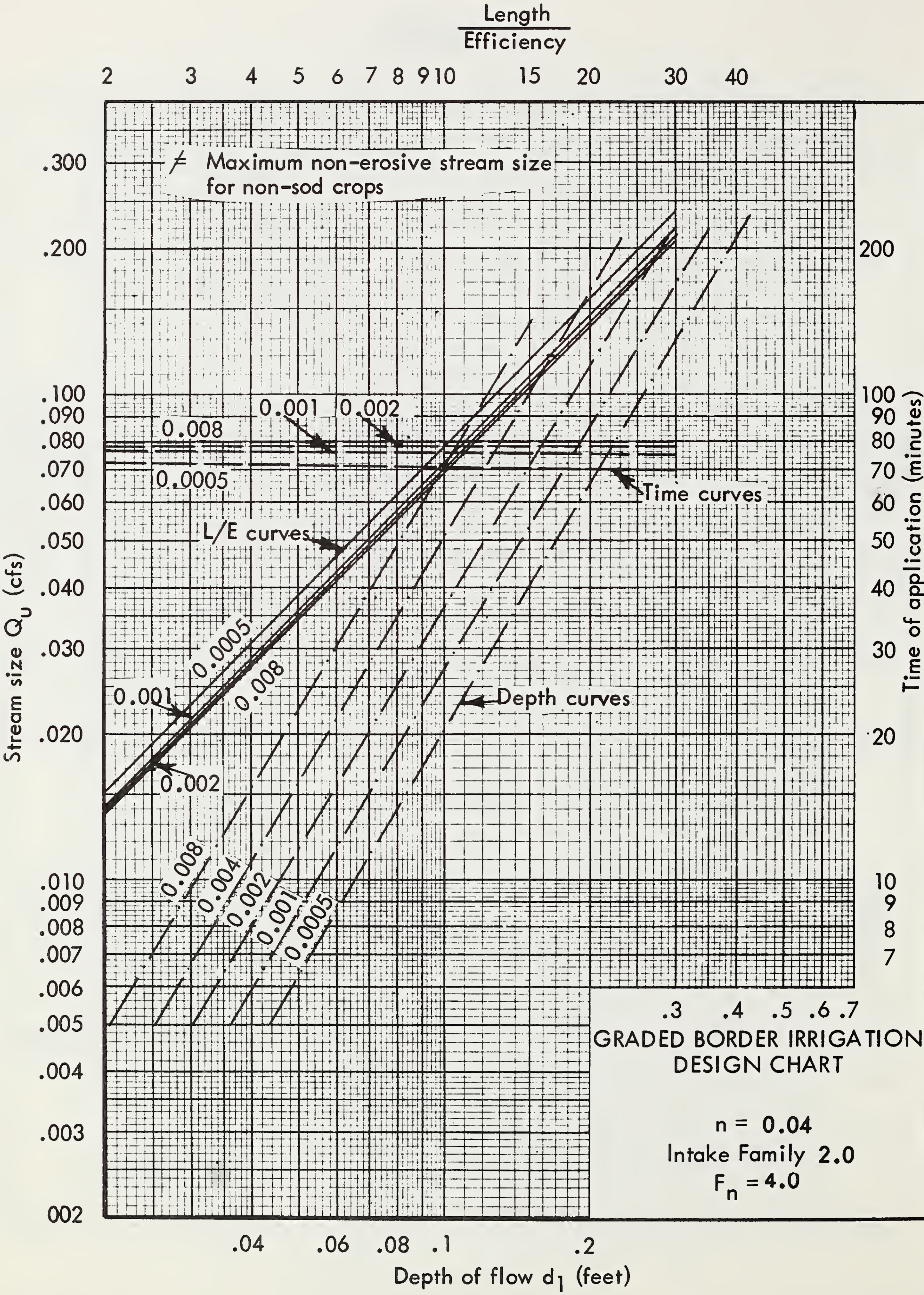


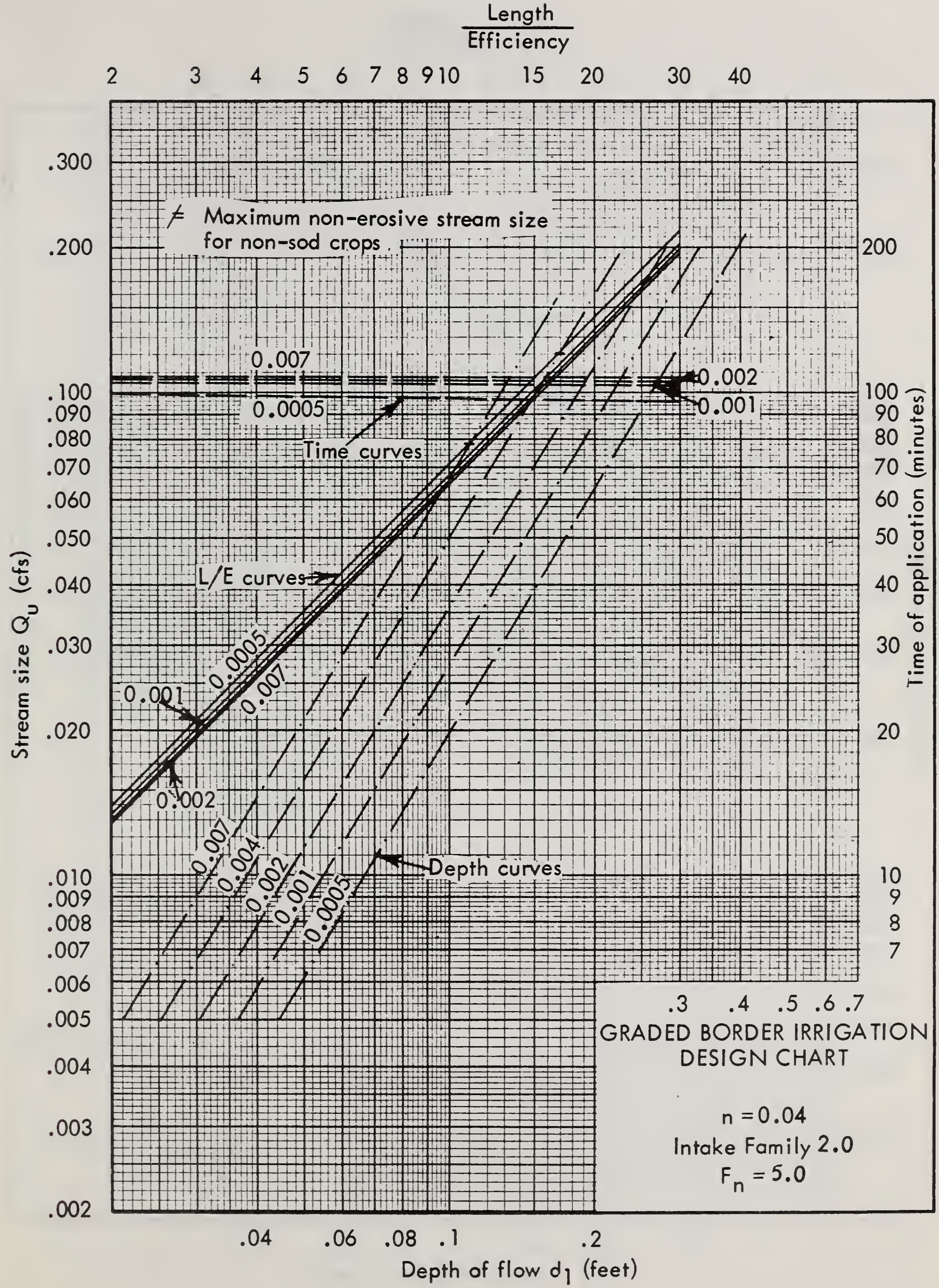
GRADED BORDER IRRIGATION DESIGN CHART

$n = 0.04$

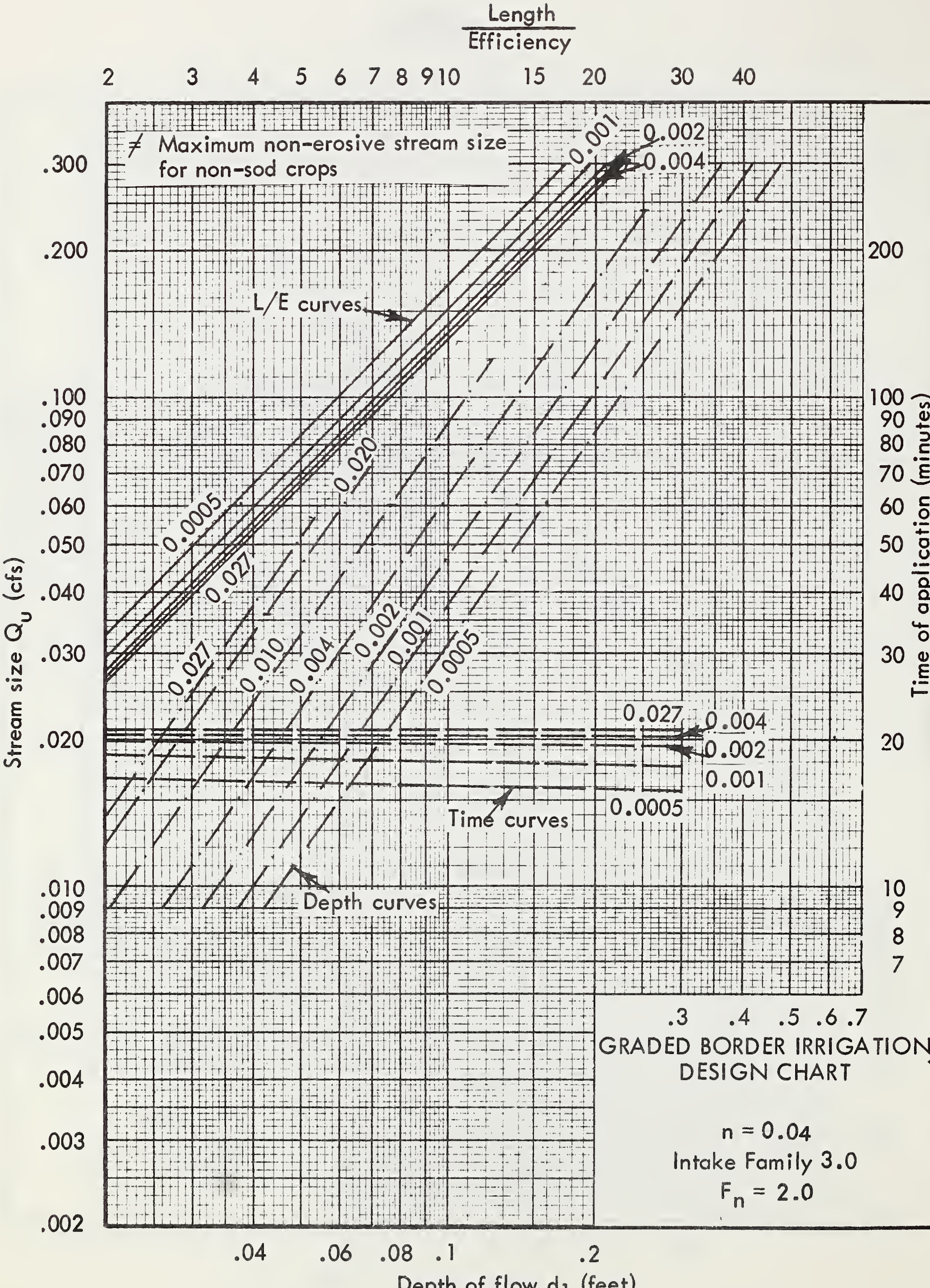
Intake Family 2.0

$F_n = 3.0$

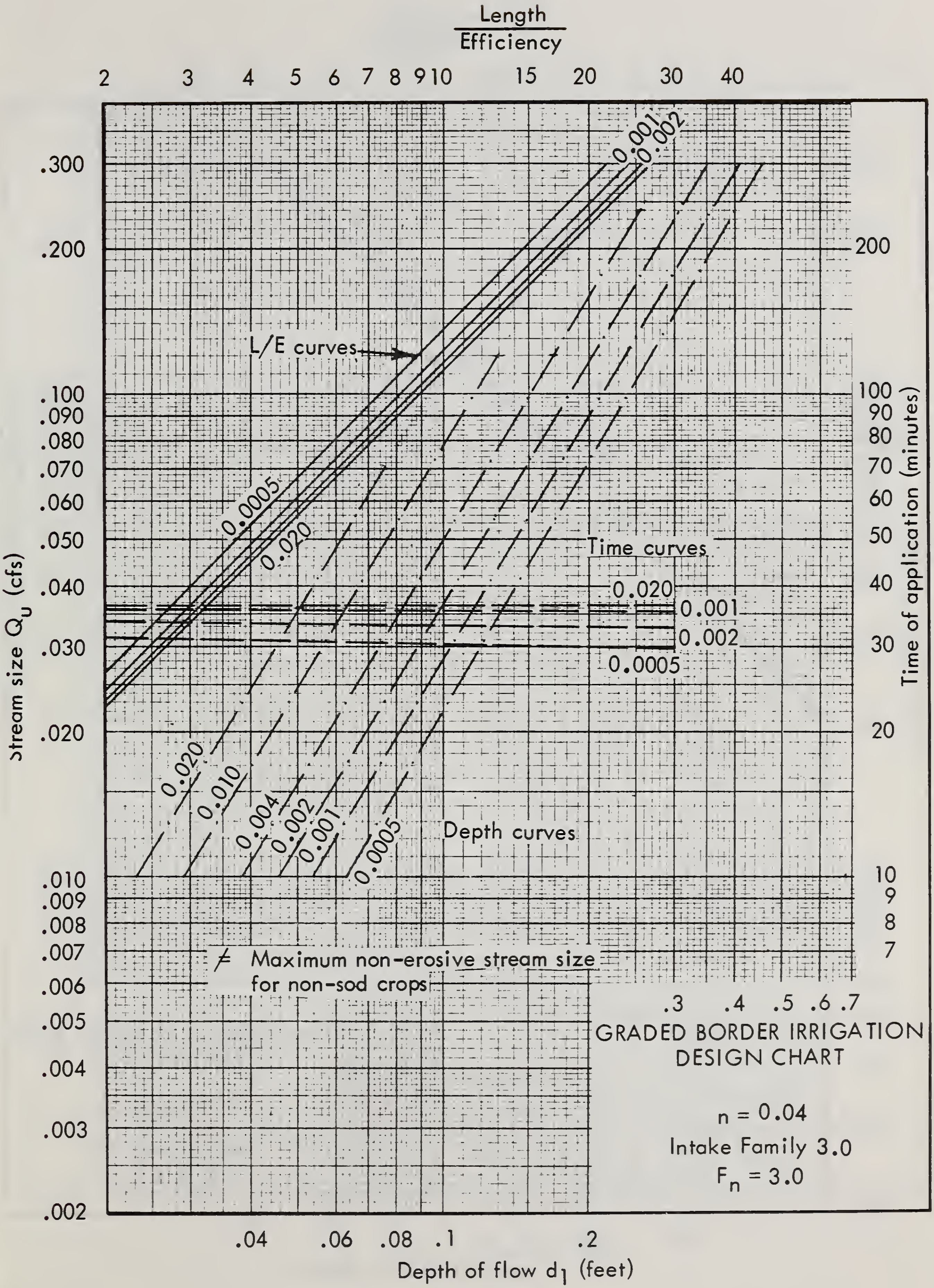

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
0.001 0.002
0.008
0.0005
Time curves
L/E curves
0.0005
0.008
0.001
0.002
Depth curves
0.008 0.004 0.002 0.001 0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 4.0

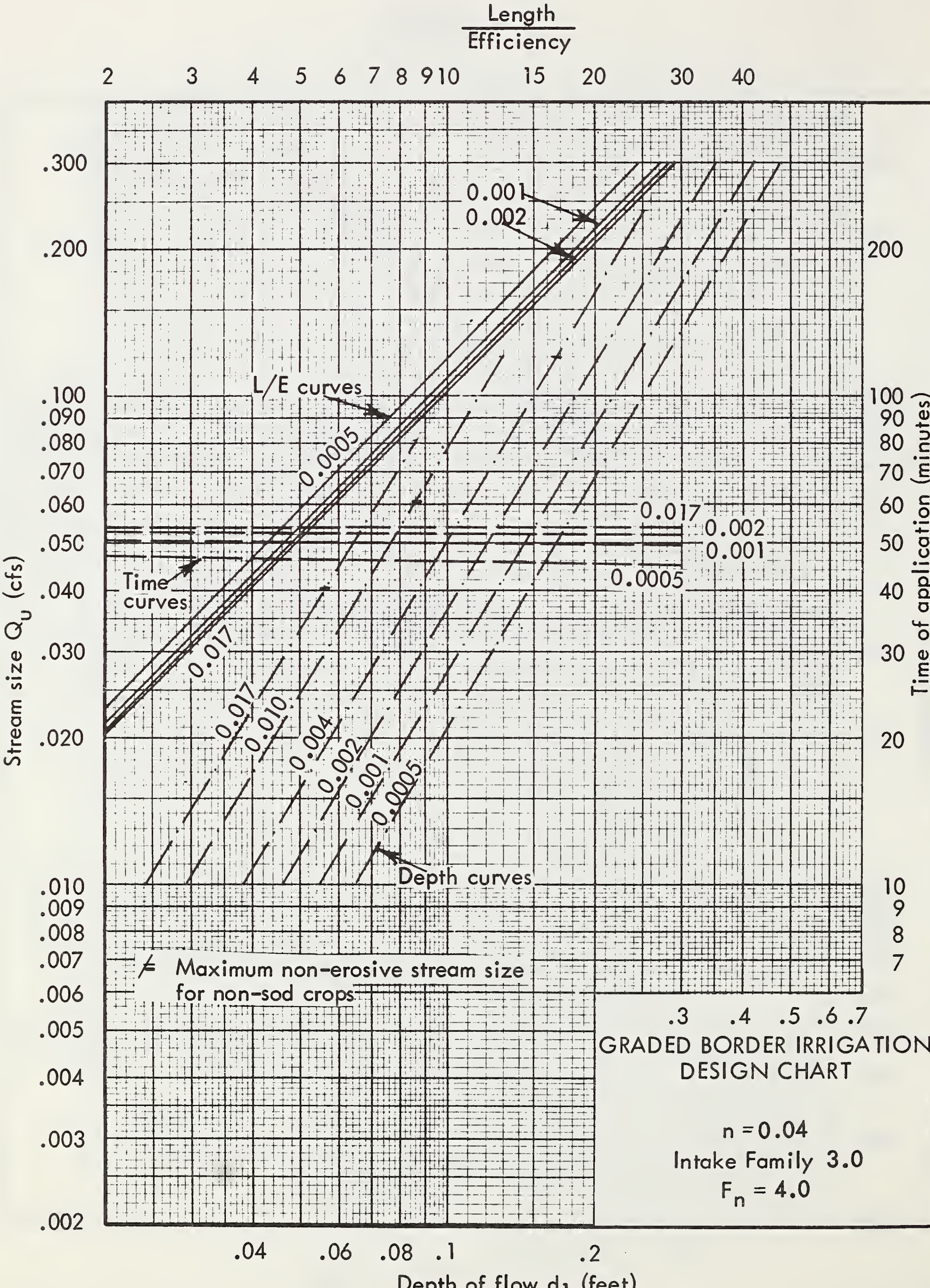


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
0.007
0.0005
0.002
0.001
Time curves
L/E curves
0.0005
0.007
0.001
0.002
0.007
0.004
0.002
0.001
0.0005
Depth curves
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 2.0
F_n = 5.0

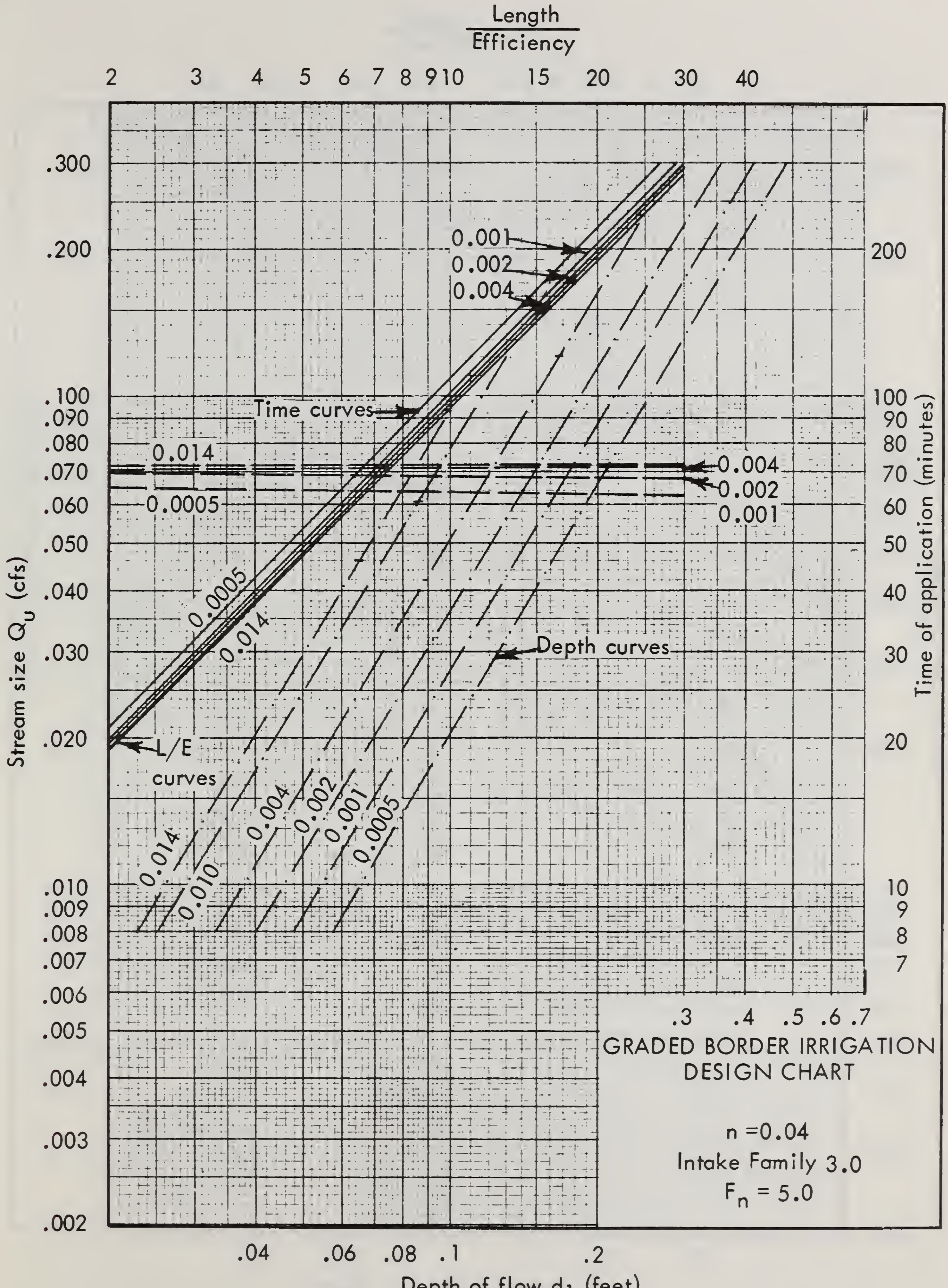


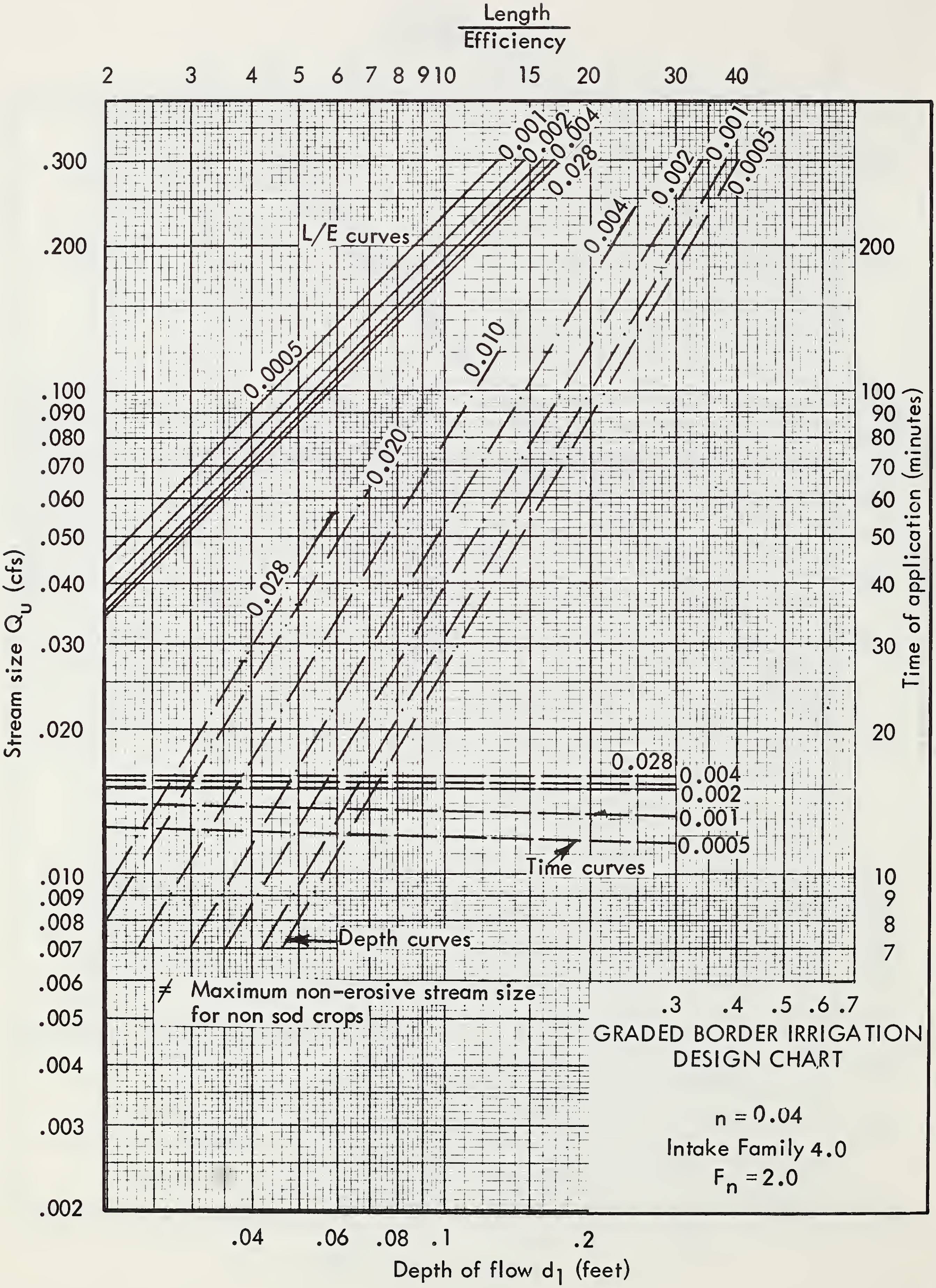
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
≠ Maximum non-erosive stream size for non-sod crops
L/E curves
Time curves
Depth curves
0.001
0.002
0.004
0.020
0.0005
0.027
0.027
0.010
0.004
0.002
0.001
0.0005
0.027
0.004
0.002
0.001
0.0005
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 2.0

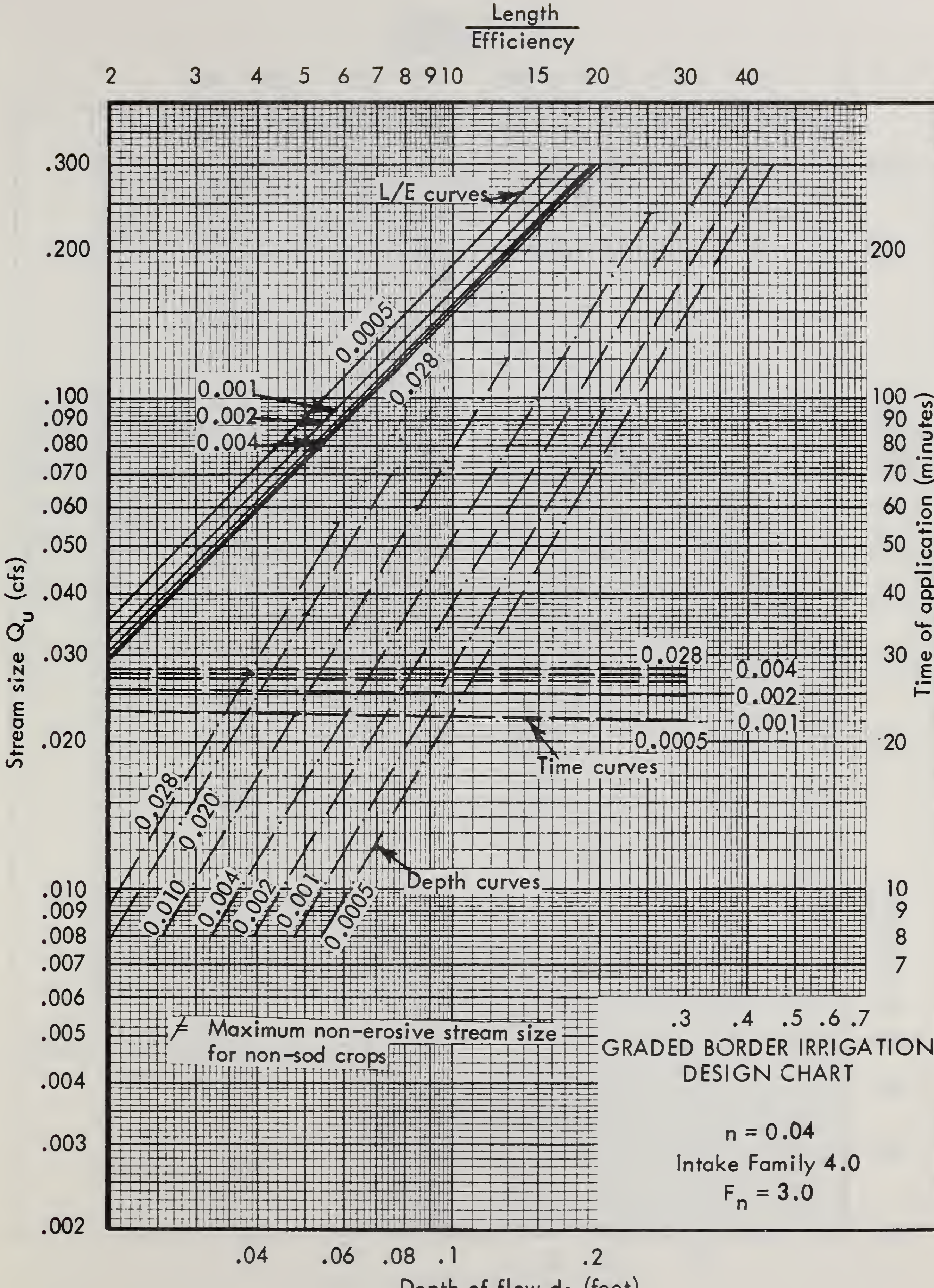

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
L/E curves
0.001
0.002
0.0005
0.020
Time curves
0.020
0.001
0.002
0.0005
0.020
0.010
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 3.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)



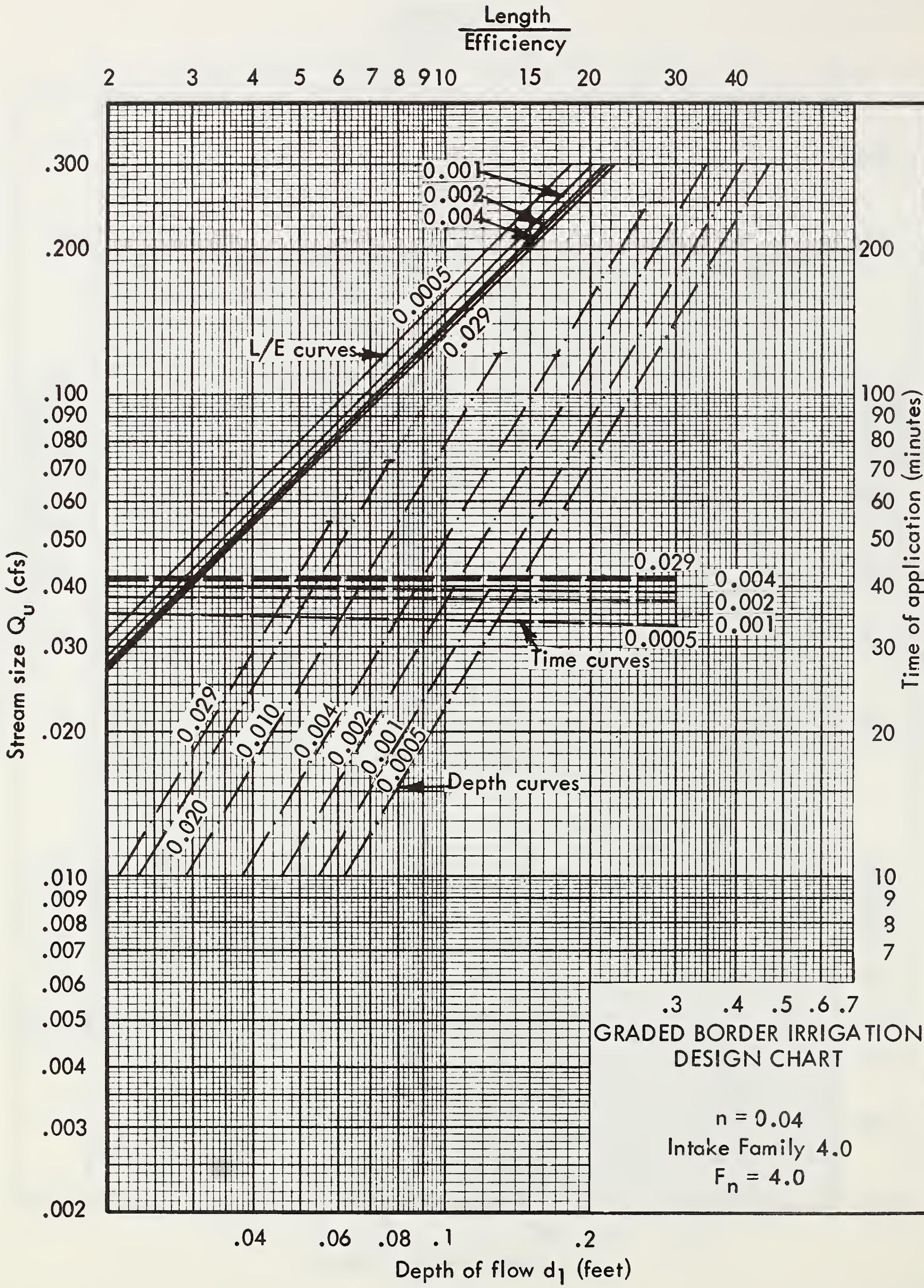
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
0.001
0.002
L/E curves
0.0005
0.017
0.017
0.002
0.001
0.0005
Time curves
0.017
0.017
0.010
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 3.0
F_n = 4.0

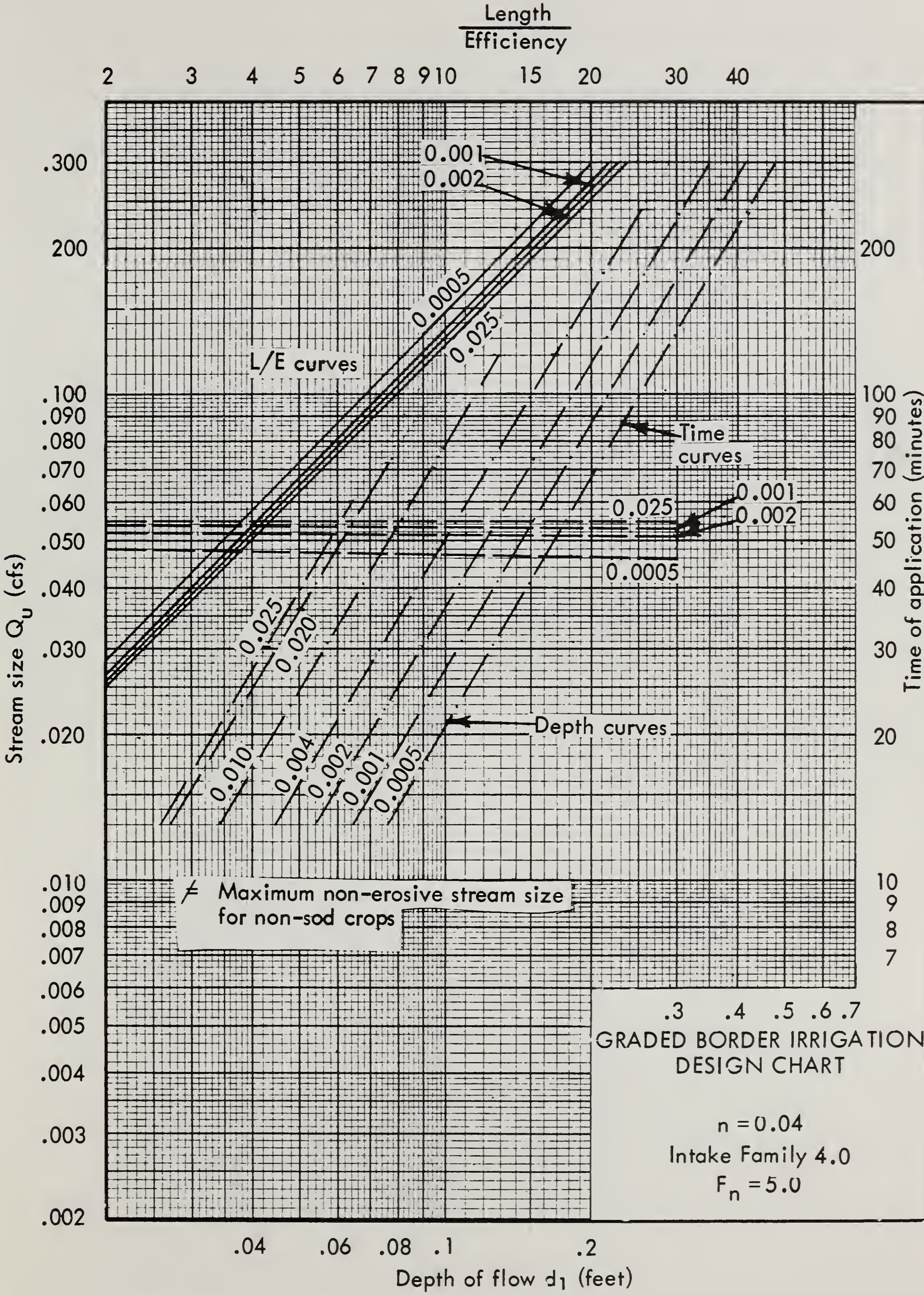

Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
Depth of flow d_1 (feet)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
0.001
0.002
0.004
Time curves
0.014
0.0005
0.004
0.002
0.001
0.0005
0.014
Depth curves
L/E curves
0.004 0.002 0.001 0.0005
0.014 0.010
GRADED BORDER IRRIGATION DESIGN CHART
n =0.04
Intake Family 3.0
F_n = 5.0

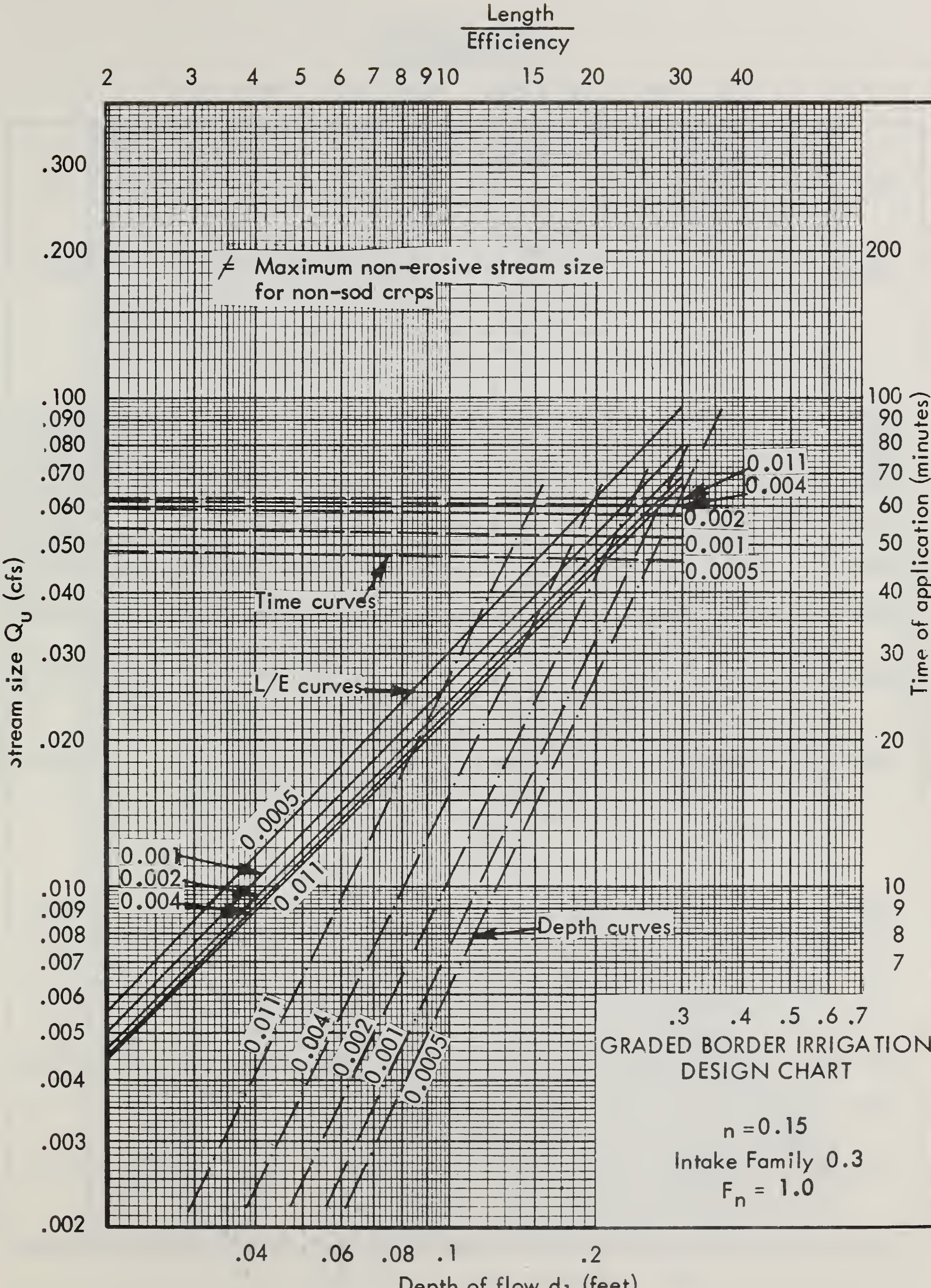

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
L/E curves
0.0005
0.001
0.002
0.004
0.028
0.010
0.020
0.028
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.028
0.004
0.002
0.001
0.0005
Time curves
Depth curves
≠ Maximum non-erosive stream size for non sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 2.0



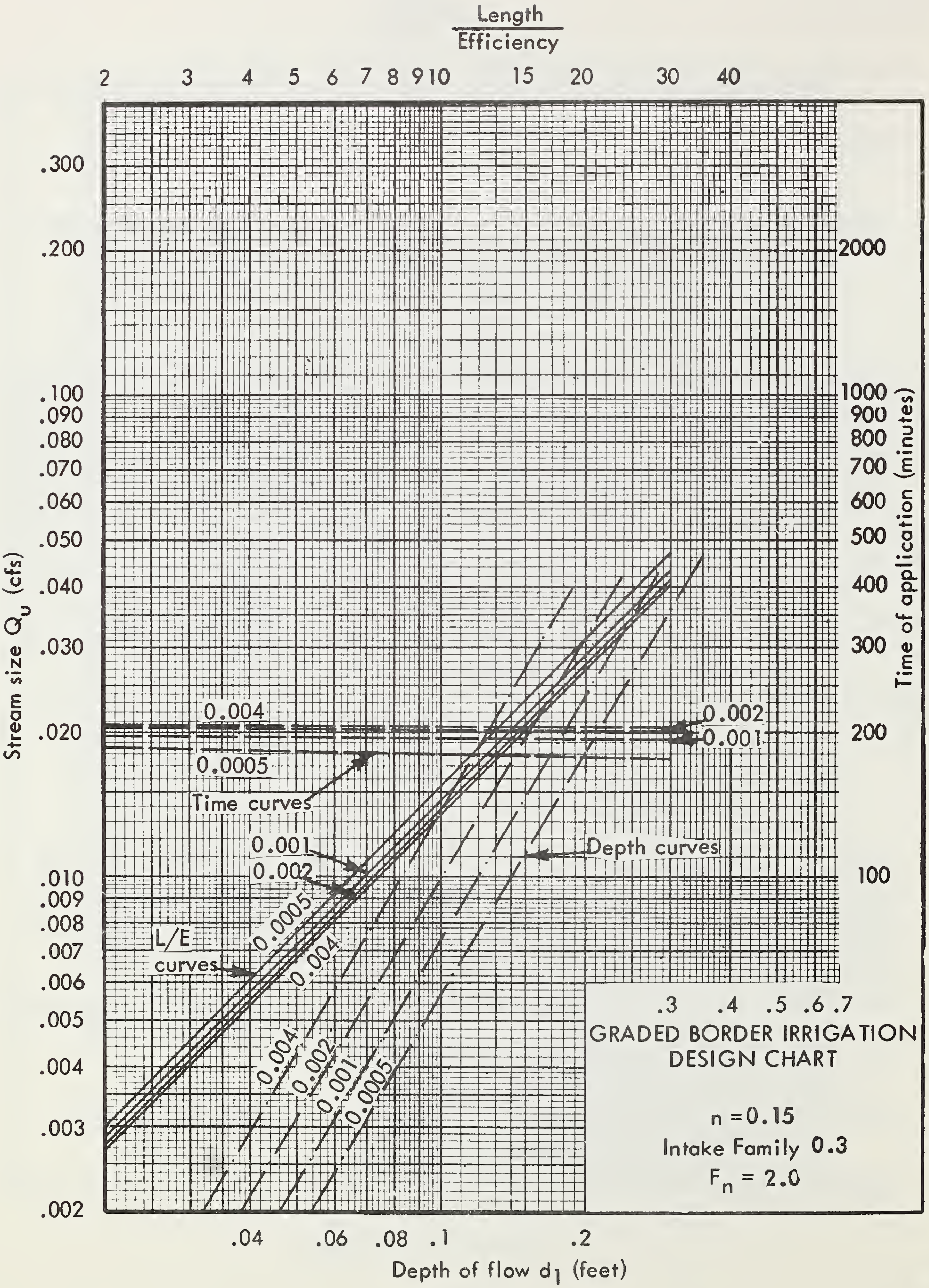
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
L/E curves
0.0005
0.001
0.002
0.004
0.028
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.028
0.004
0.002
0.001
0.0005
Time curves
0.028
0.020
0.010
0.004
0.002
0.001
0.0005
Depth curves
.3 .4 .5 .6 .7
Maximum non-erosive stream size for non-sod crops
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 3.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

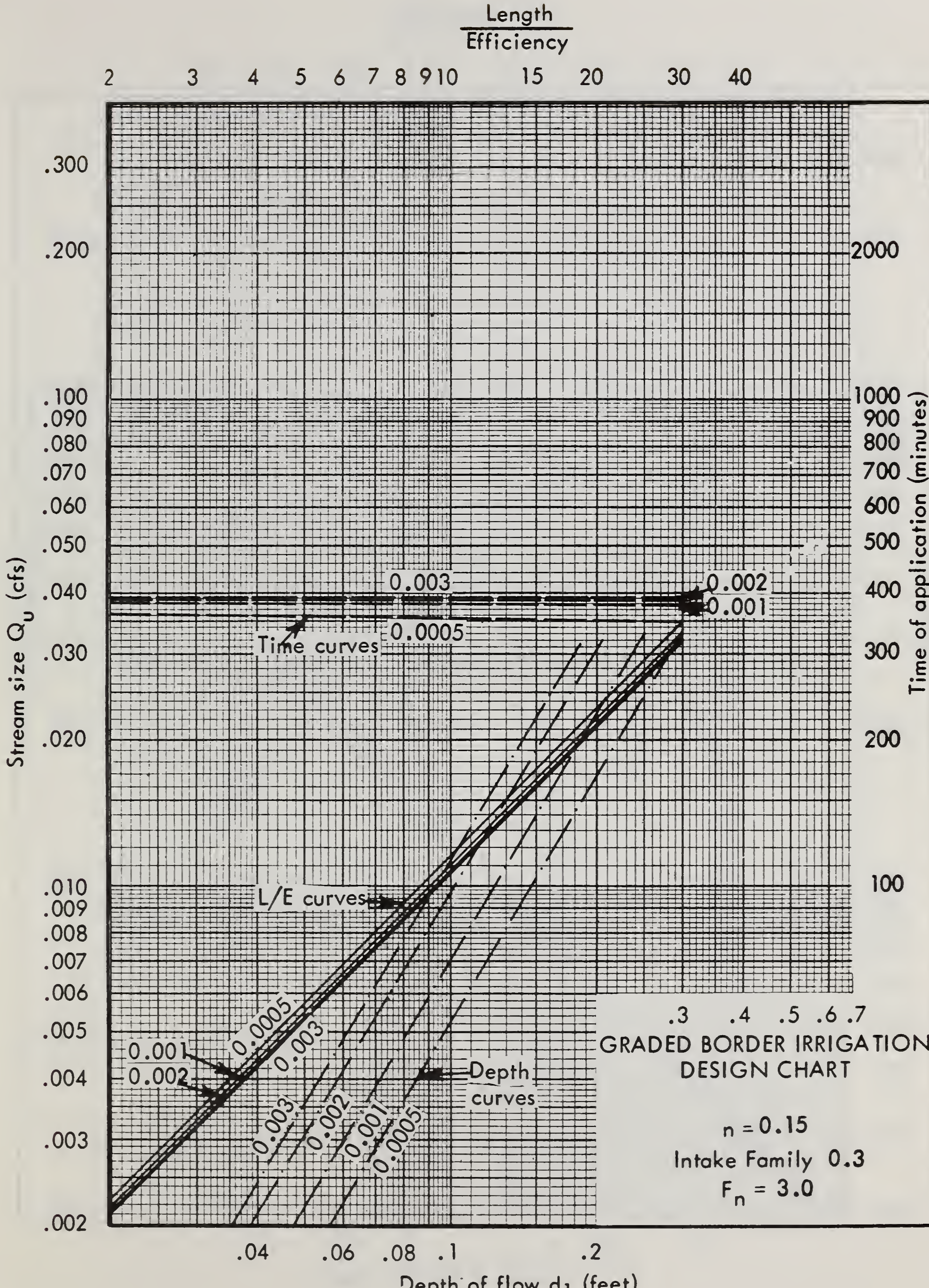

Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
L/E curves
0.001
0.002
0.004
0.0005
0.029
Time curves
0.029
0.004
0.002
0.001
0.0005
Depth curves
0.029
0.020
0.010
0.004
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 4.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
0.001
0.002
0.0005
0.025
L/E curves
Time curves
0.025
0.001
0.002
0.0005
0.025
0.020
0.010
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.04
Intake Family 4.0
F_n = 5.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
Maximum non-erosive stream size for non-sod crops
200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
0.011
0.004
0.002
0.001
0.0005
Time curves
L/E curves
0.0005
0.001
0.002
0.004
0.011
Depth curves
0.011
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 1.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
2000
1000
900
800
700
600
500
400
300
200
100
Time of application (minutes)
0.004
0.0005
Time curves
0.002
0.001
0.001
0.002
Depth curves
0.0005
0.004
L/E curves
0.004
0.002
0.001
0.0005
.04 .06 .08 .1 .2
.3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.3
F_n = 2.0

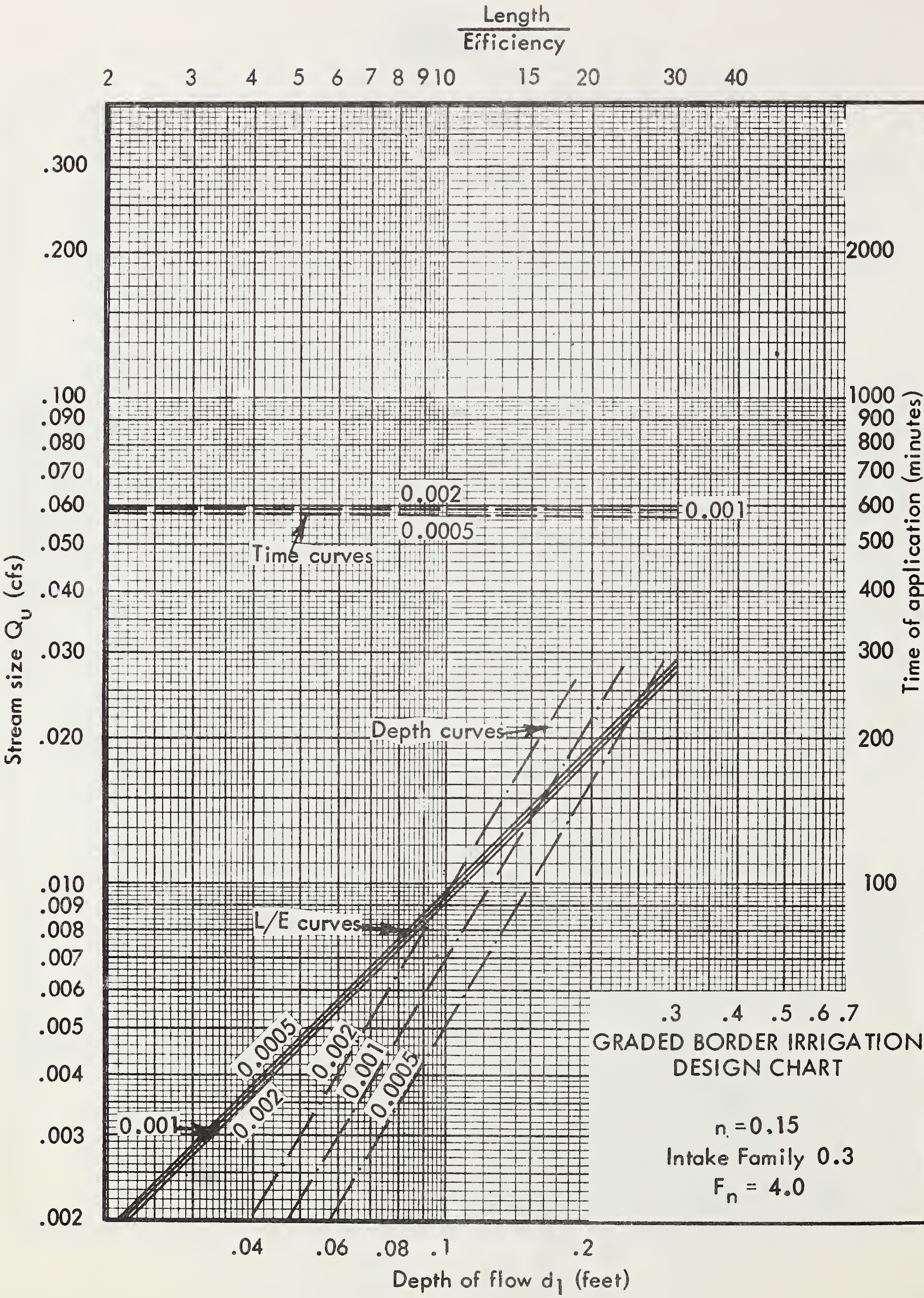


GRADED BORDER IRRIGATION DESIGN CHART

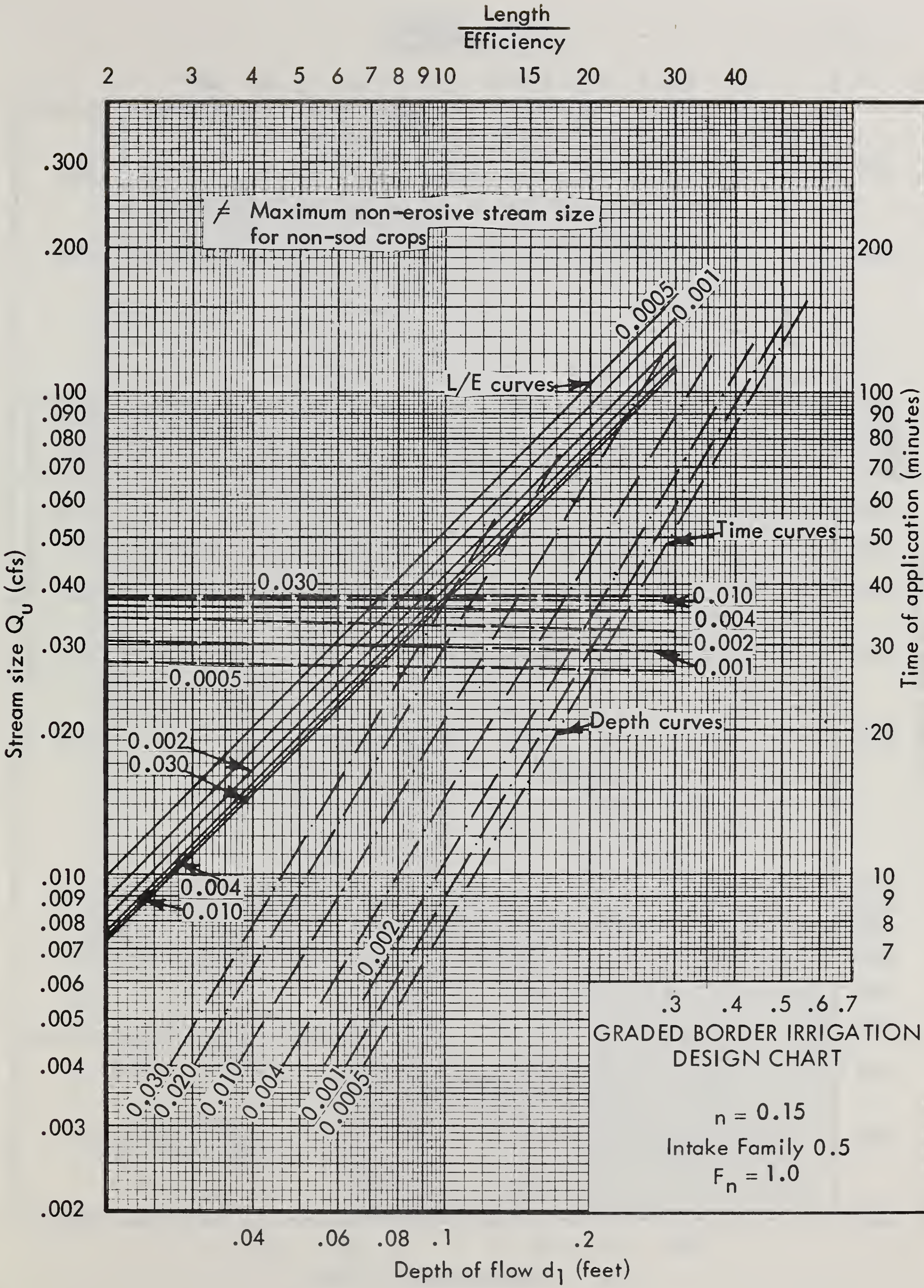
n = 0.15

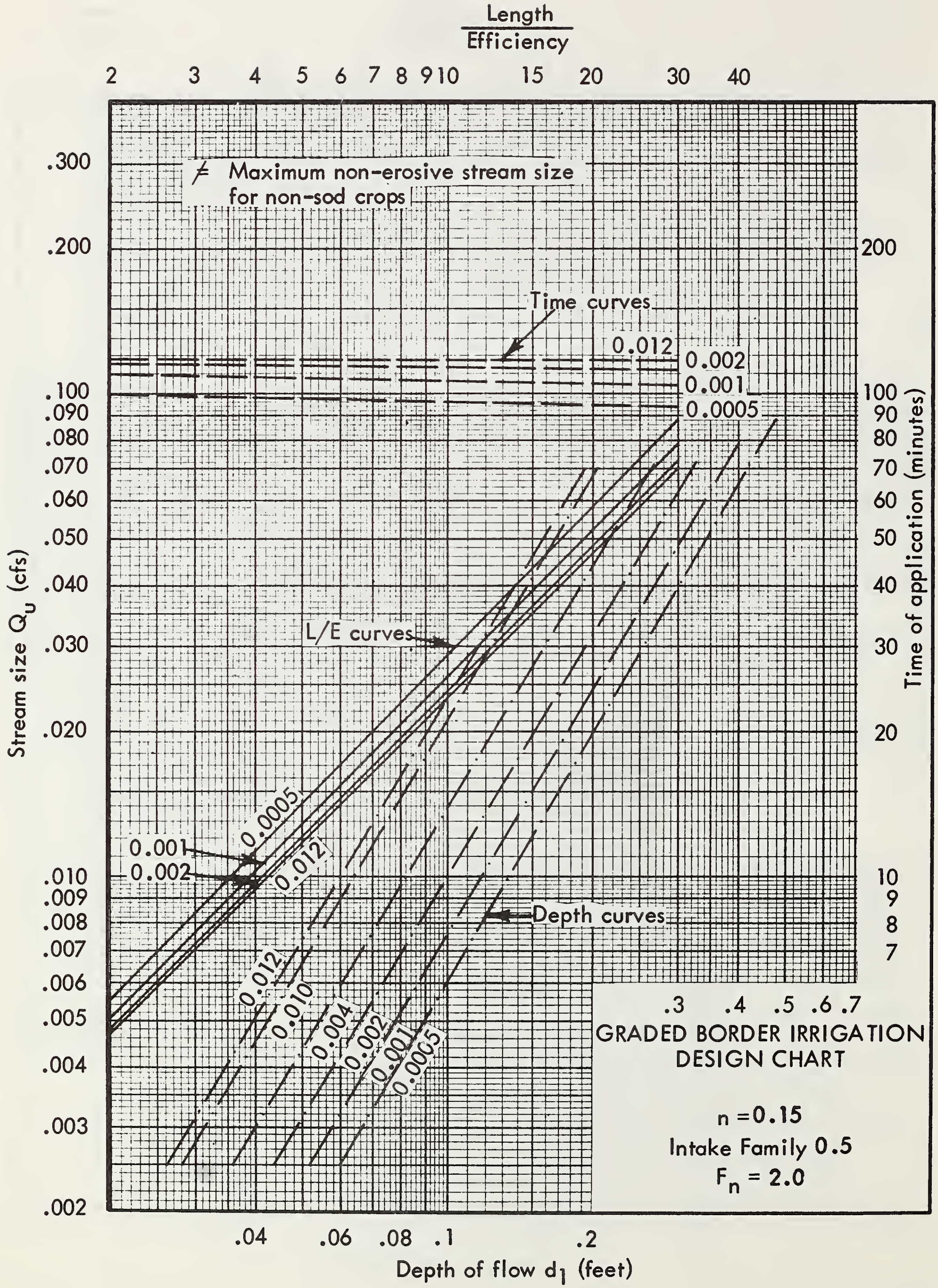
Intake Family 0.3

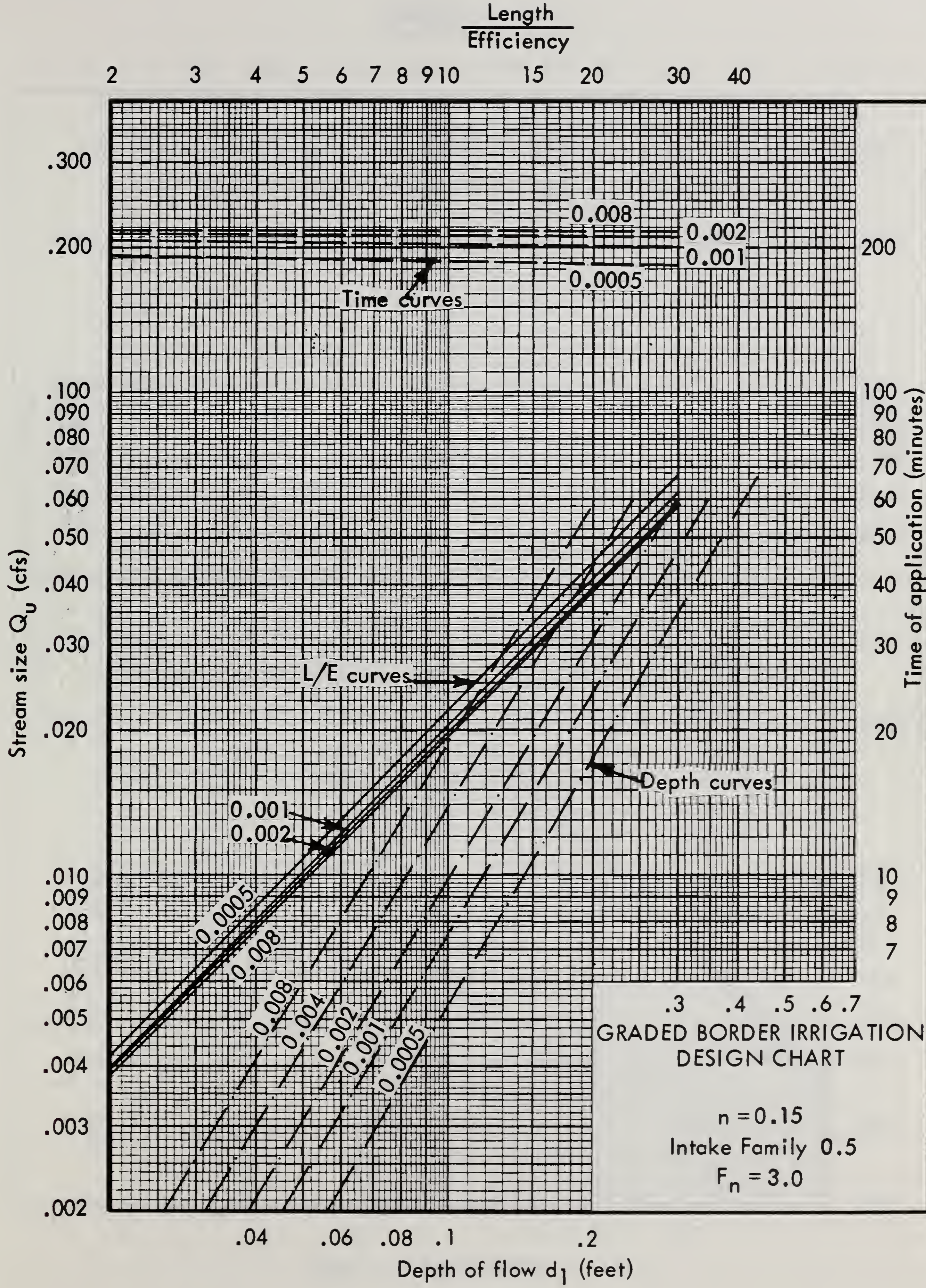
F_n = 3.0

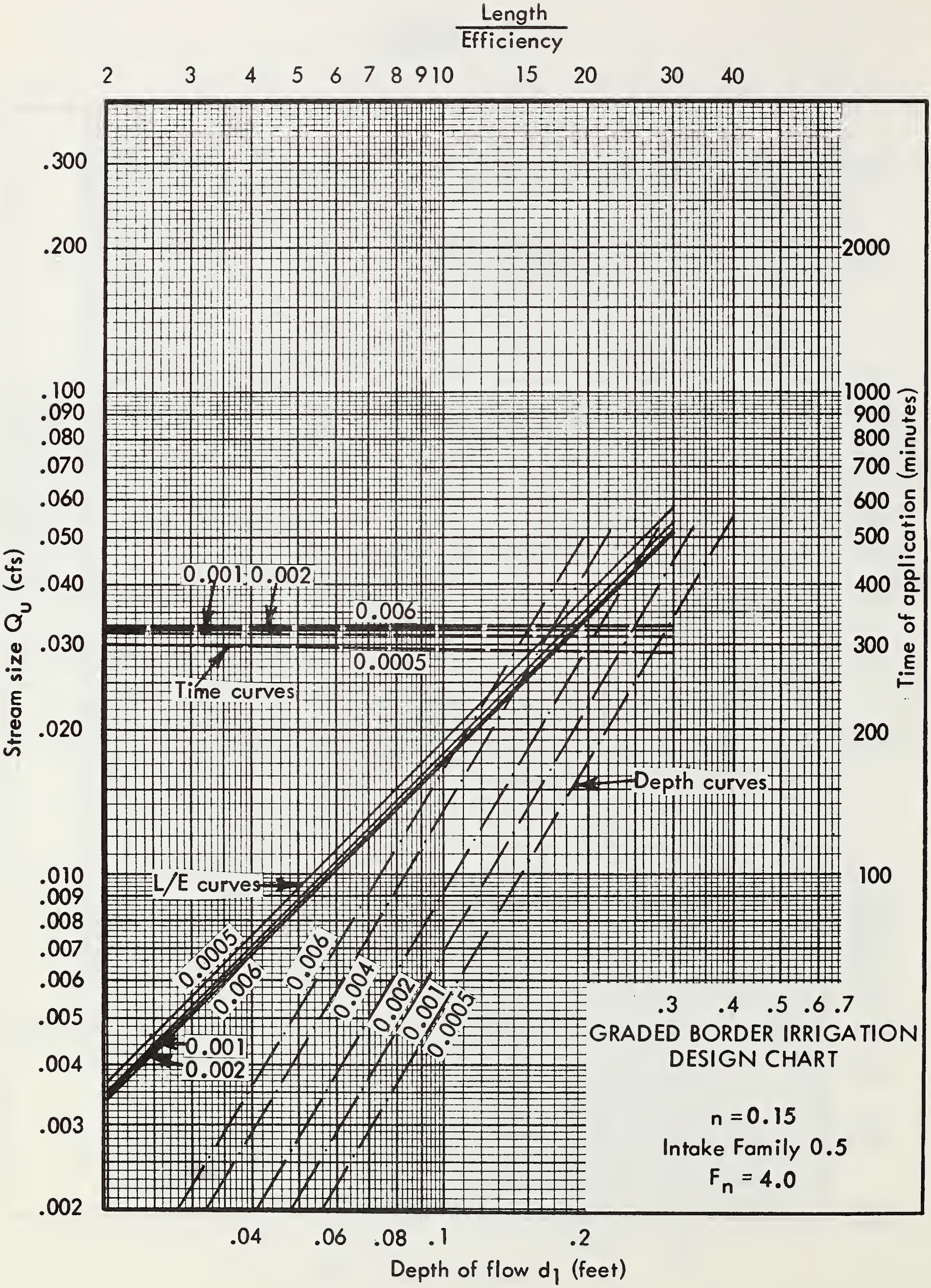


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
2000
1000
900
800
700
600
500
400
300
200
100
0.002
0.0005
0.001
Time curves
Depth curves
L/E curves
0.0005
0.002
0.001
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 0.3
F_n = 4.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
0.0005
0.001
Time curves
0.030
0.010
0.004
0.002
0.001
0.0005
Depth curves
0.002
0.030
0.004
0.010
0.030 0.020 0.010 0.004 0.001 0.0005
0.002
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 1.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Time curves
0.012
0.002
0.001
0.0005
L/E curves
0.0005
0.001
0.002
0.012
Depth curves
0.012
0.010
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 2.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
0.008
0.002
0.001
0.0005
Time curves
L/E curves
Depth curves
0.001
0.002
0.0005
0.008
0.008
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 3.0

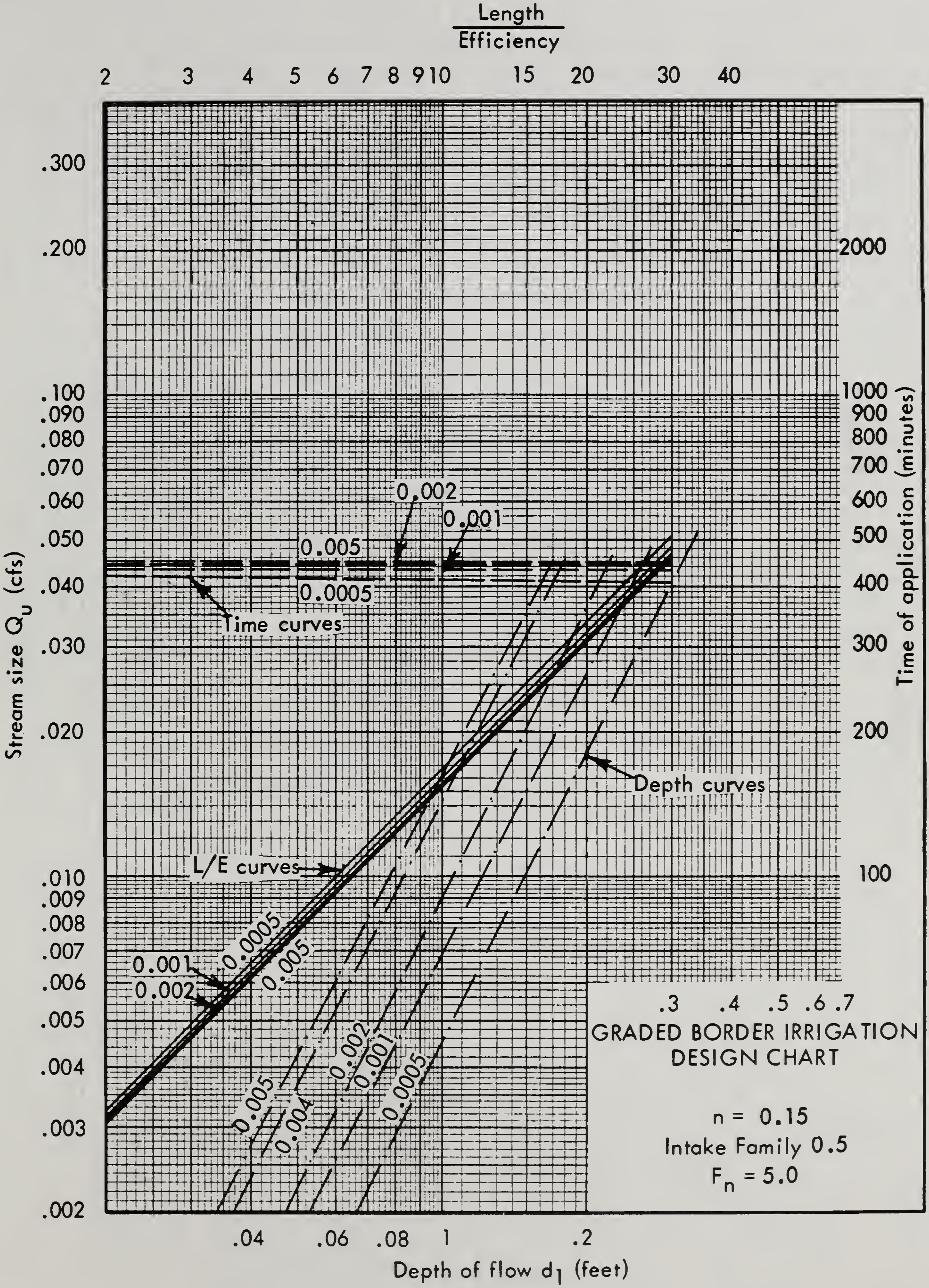


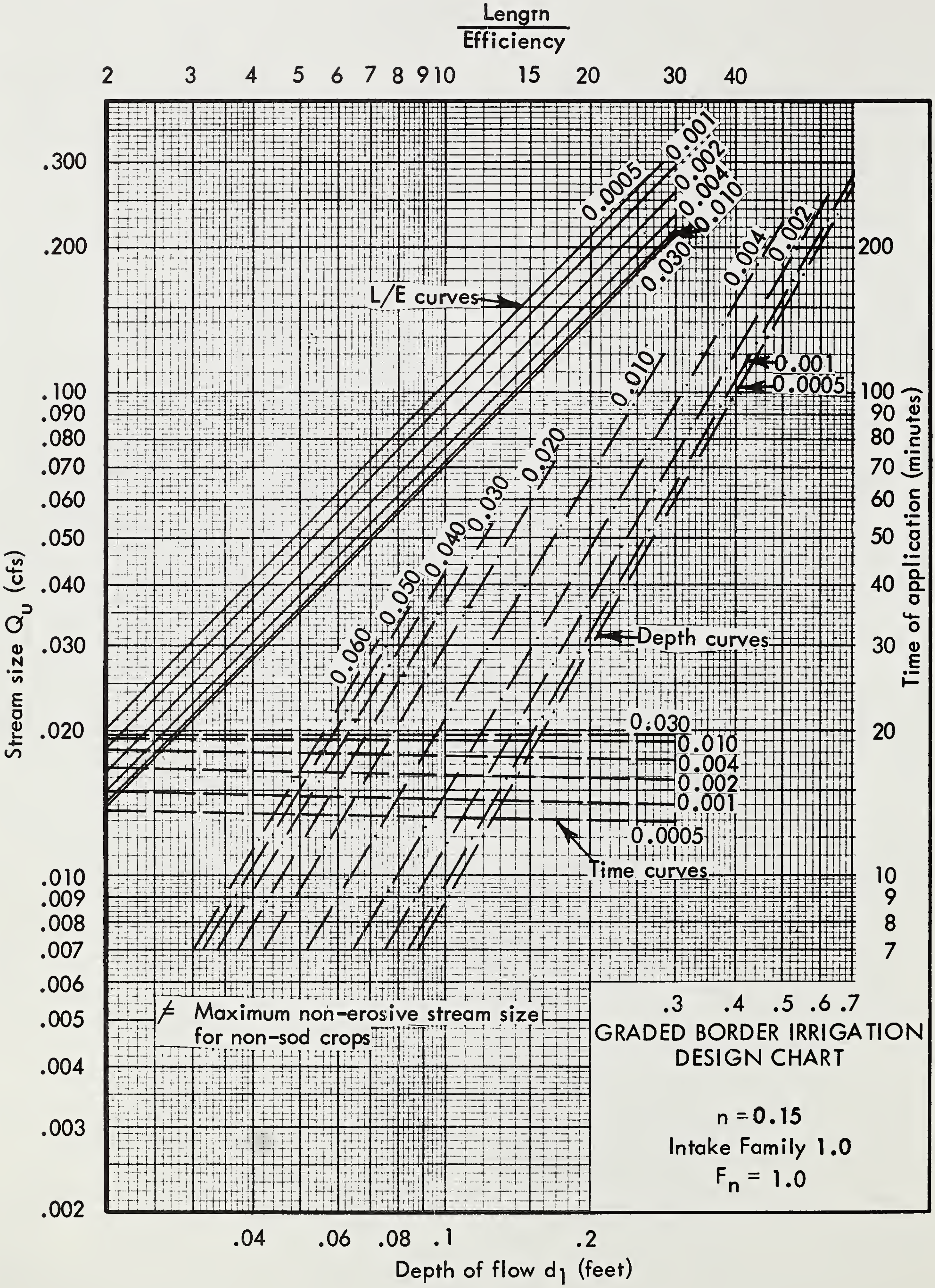
GRADED BORDER IRRIGATION DESIGN CHART

$n = 0.15$

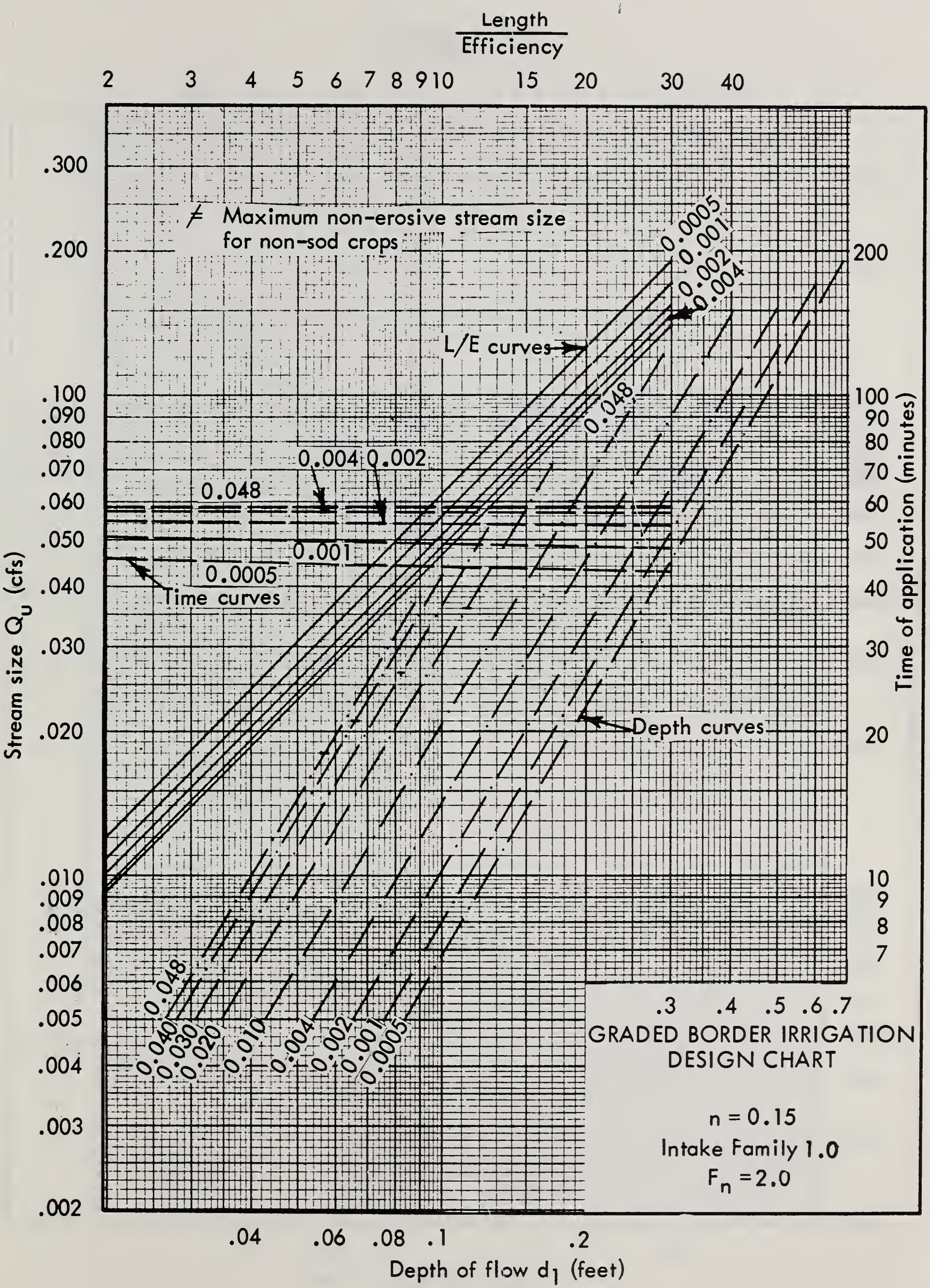
Intake Family 0.5

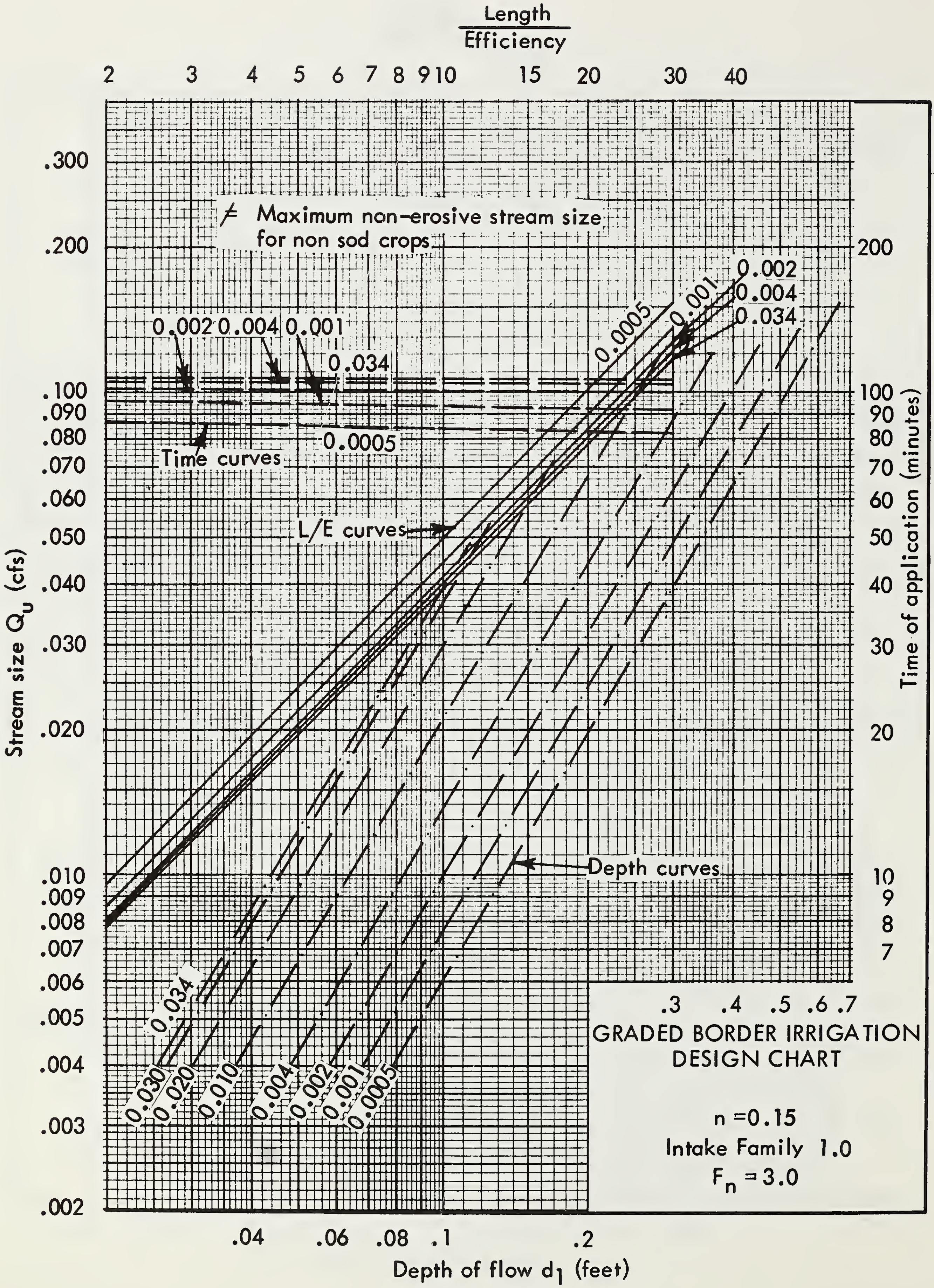
$F_n = 4.0$

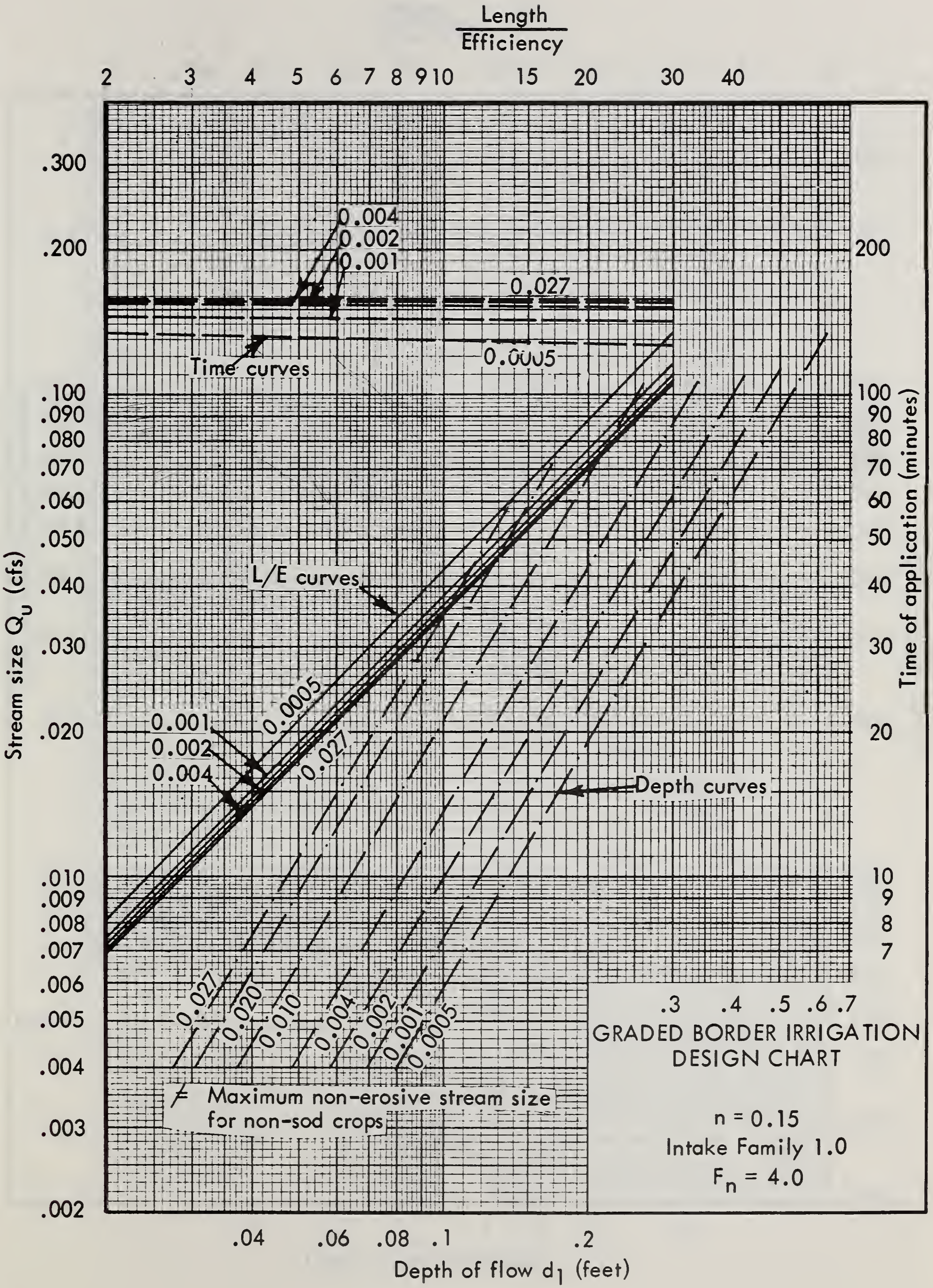

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
2000
1000
900
800
700
600
500
400
300
200
100
0.002
0.001
0.005
0.0005
Time curves
Depth curves
L/E curves
0.0005
0.005
0.001
0.002
0.002
0.001
0.0005
0.005
0.004
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.15
Intake Family 0.5
F_n = 5.0
.04 .06 .08 1 .2
Depth of flow d_1 (feet)

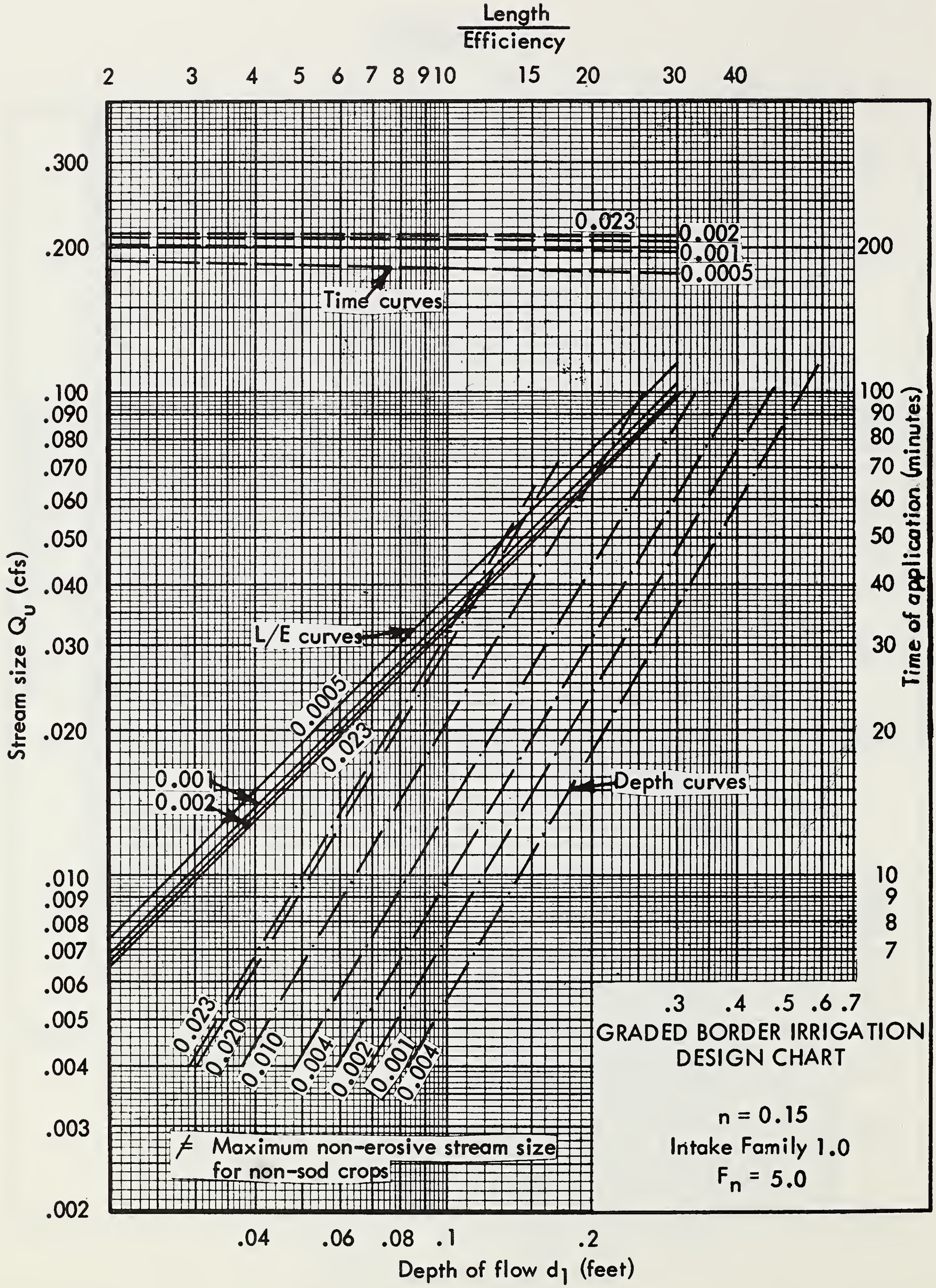


Lengrn
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
L/E curves
0.0005 0.001 0.002 0.004 0.010 0.030
0.004 0.002 0.001 0.0005
0.010 0.020 0.030 0.040 0.050 0.060
Depth curves
0.030 0.010 0.004 0.002 0.001 0.0005
Time curves
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 1.0

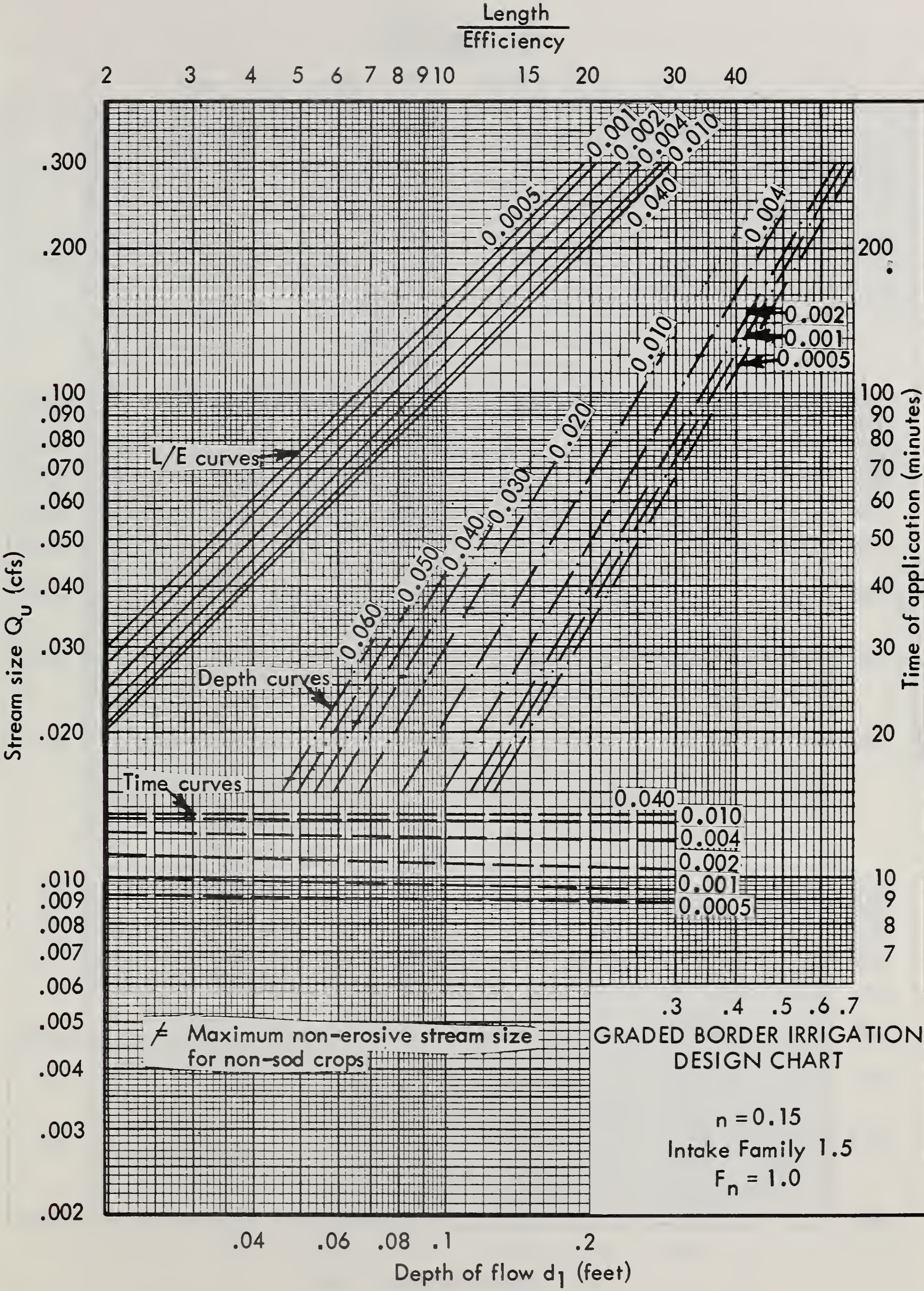

Length / Efficiency
2
3
4
5
6
7
8
9
10
15
20
30
40
Maximum non-erosive stream size for non-sod crops
L/E curves
0.0005
0.001
0.002
0.004
0.048
0.004
0.002
0.048
0.001
0.0005
Time curves
Depth curves
0.048
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
.04
.06
.08
.1
.2
.3
.4
.5
.6
.7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 2.0

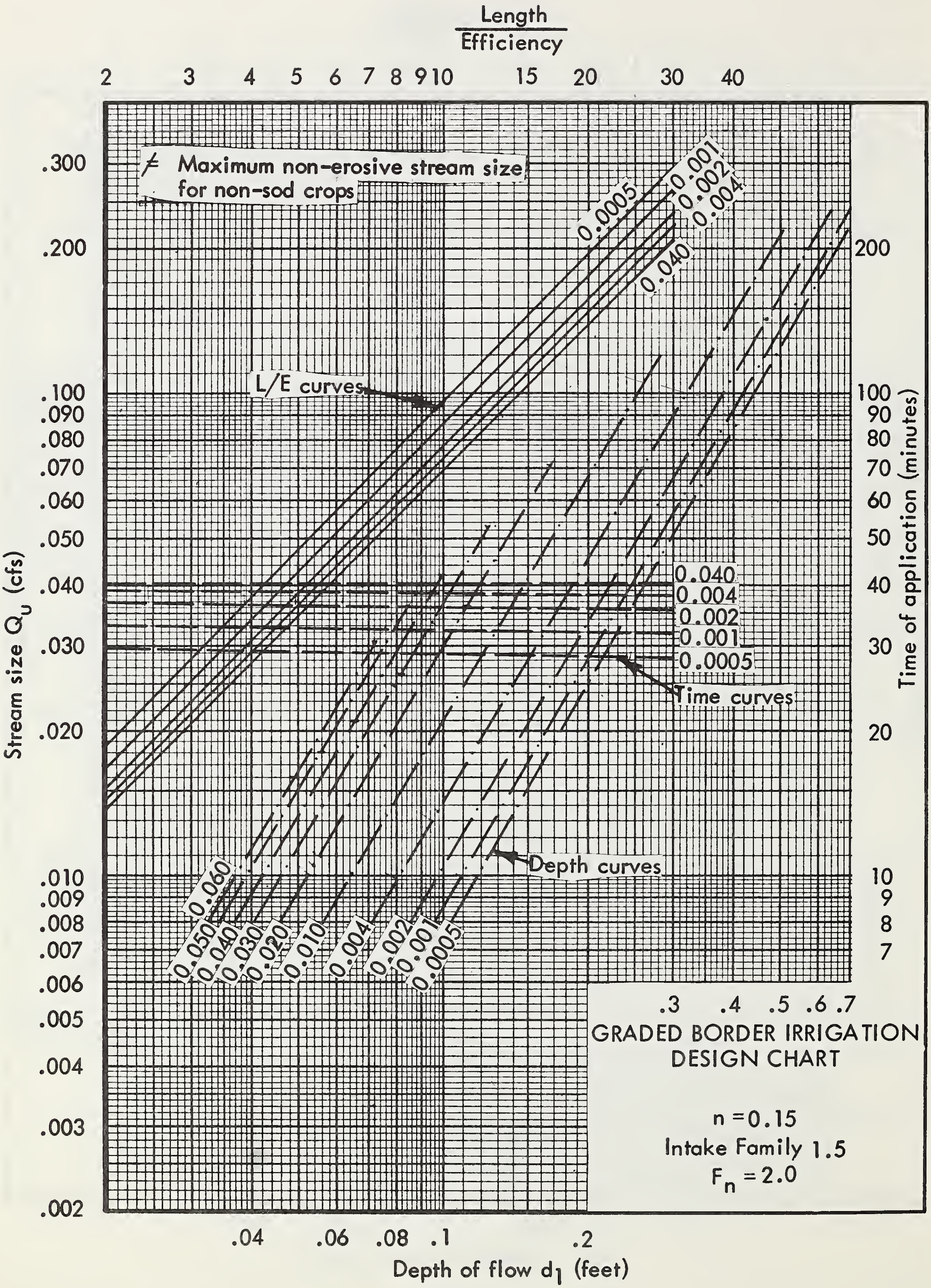

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non sod crops
0.002 0.004 0.001
0.034
0.0005
Time curves
L/E curves
0.0005
0.001
0.002
0.004
0.034
Depth curves
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.034
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 1.0
F_n = 3.0

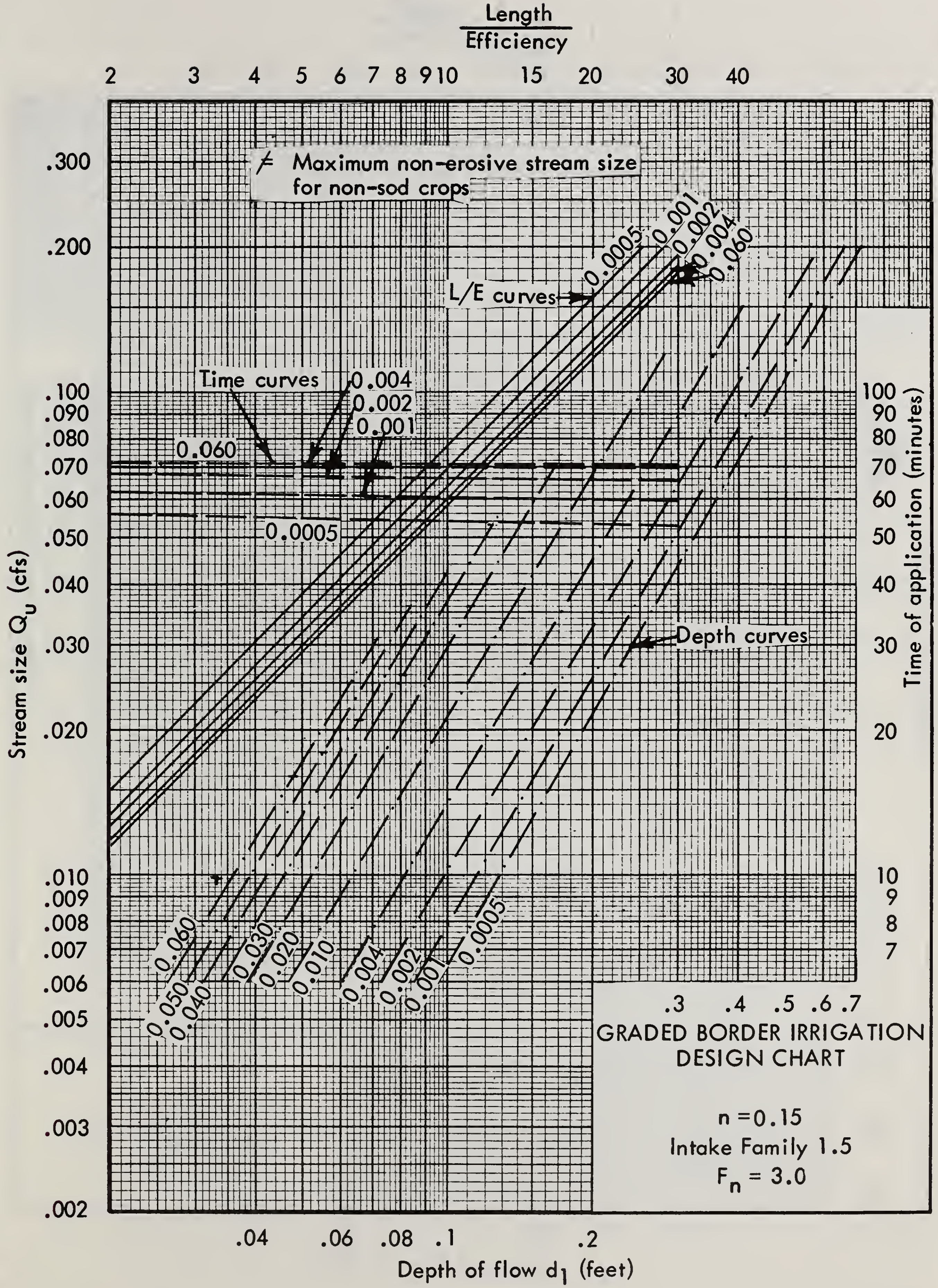

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.004
0.002
0.001
0.027
0.0005
Time curves
L/E curves
0.0005
0.001
0.002
0.004
0.027
Depth curves
0.027
0.020
0.010
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 4.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)



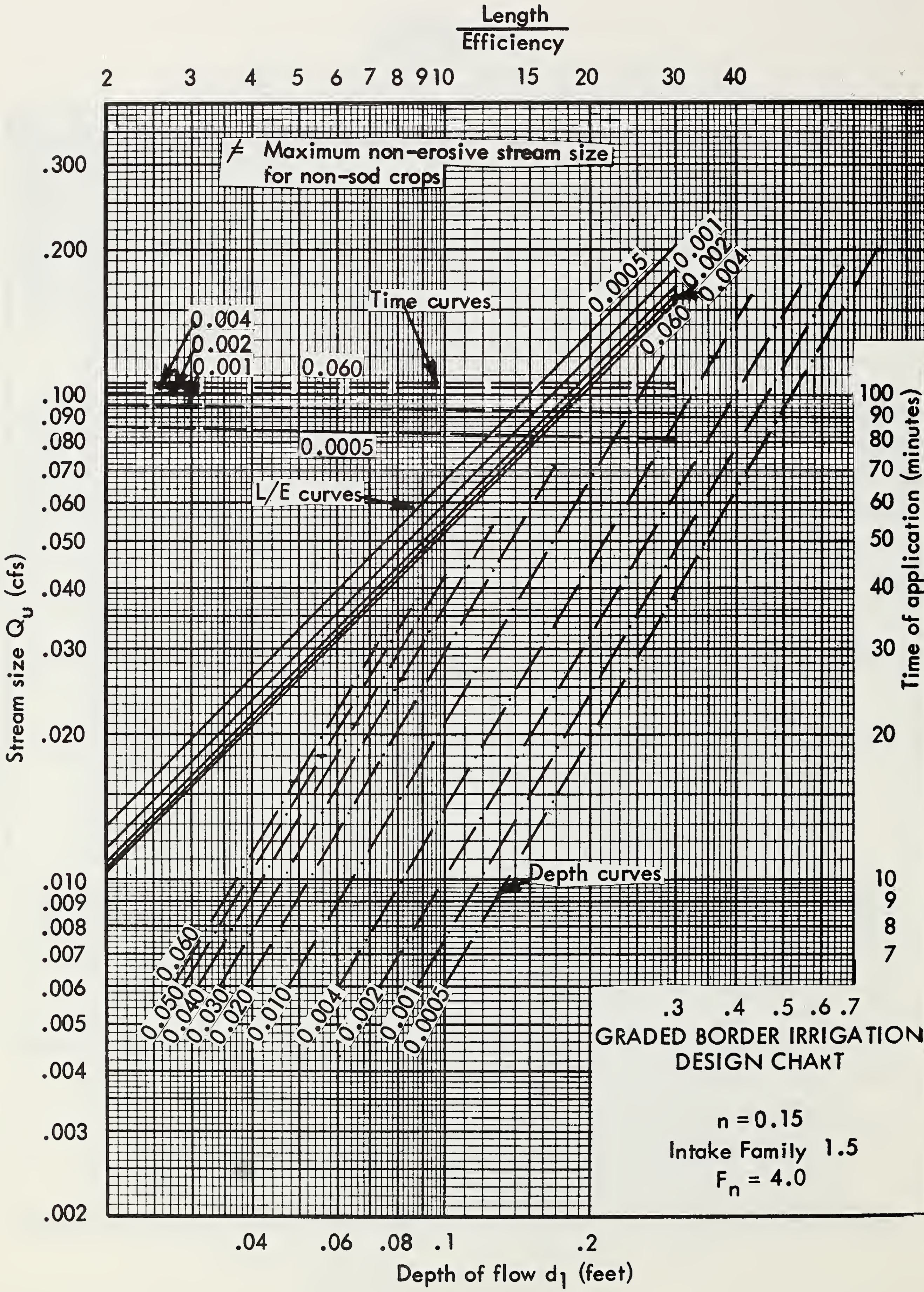
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
0.023
0.002
0.001
0.0005
Time curves
L/E curves
0.0005
0.023
0.001
0.002
Depth curves
0.023
0.020
0.010
0.004
0.002
0.001
0.004
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.0
F_n = 5.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.0005
0.001
0.002
0.004
0.010
0.040
0.004
0.002
0.001
0.0005
0.010
0.020
0.030
0.040
0.050
0.060
L/E curves
Depth curves
Time curves
0.040
0.010
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 1.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

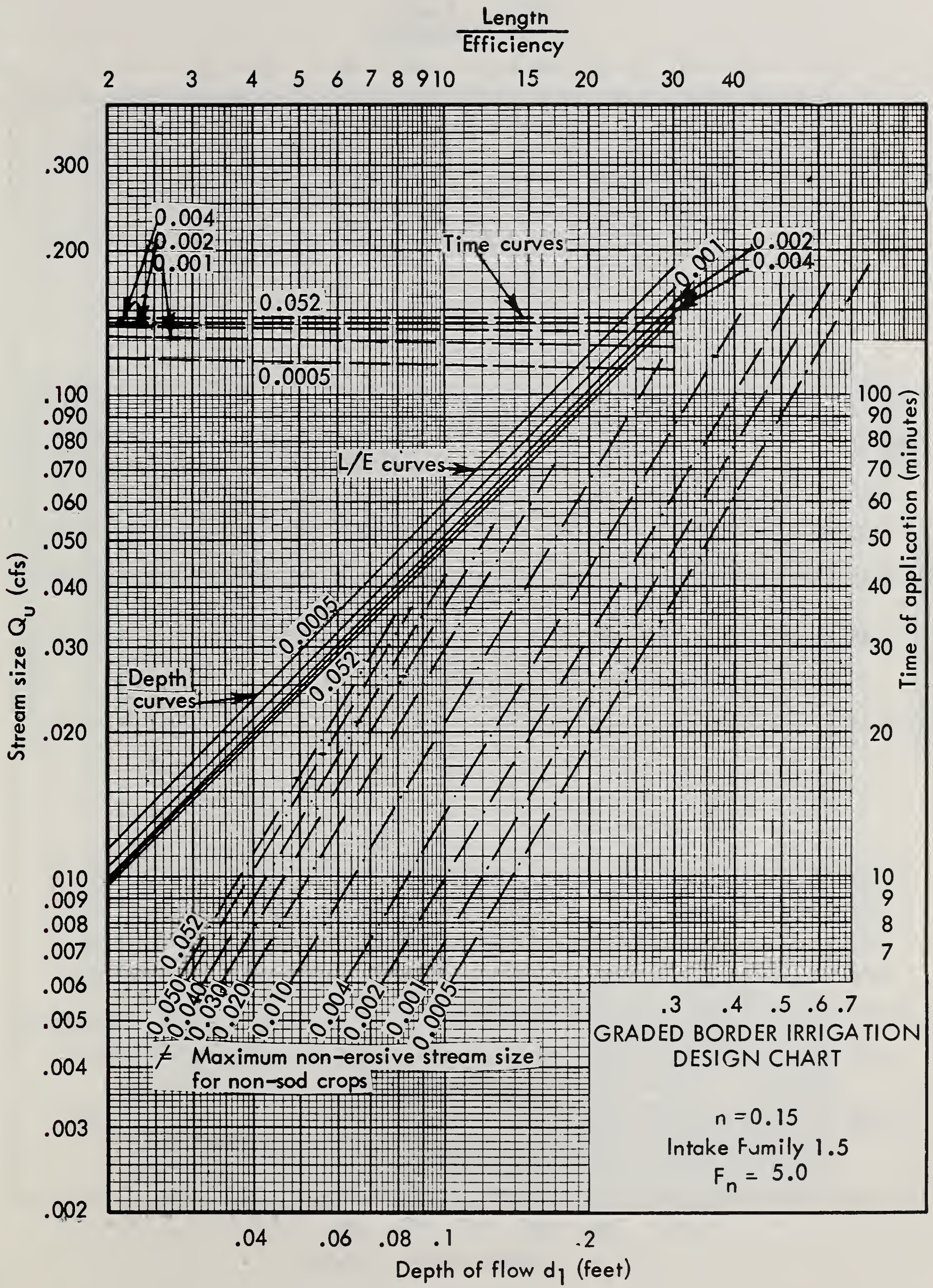

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
0.0005
0.001
0.002
0.004
0.040
L/E curves
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.040
0.004
0.002
0.001
0.0005
Time curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 2.0



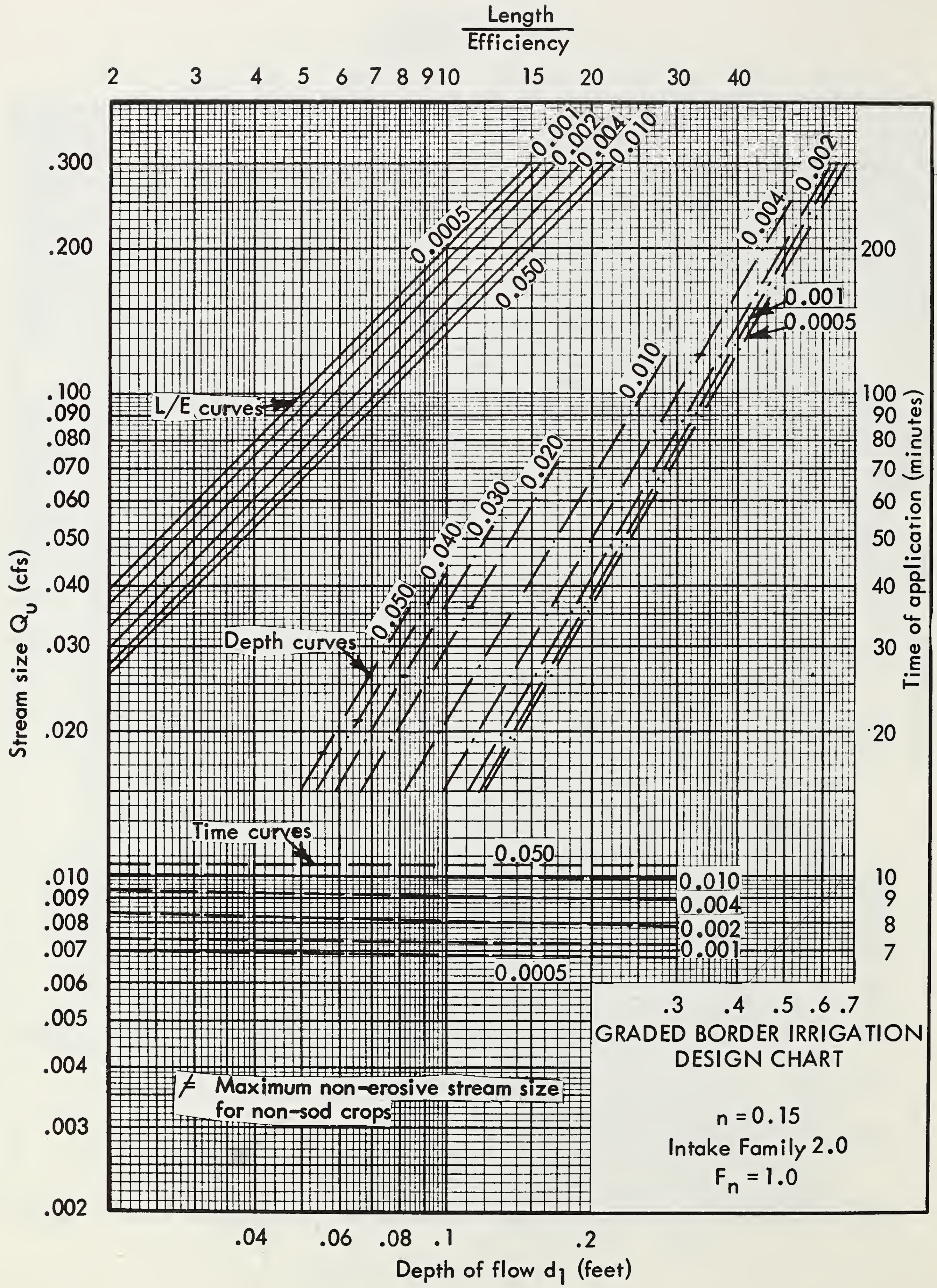
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
0.0005 0.001 0.002 0.004 0.060
Time curves
0.004
0.002
0.001
0.060
0.0005
Depth curves
0.060 0.050 0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 3.0

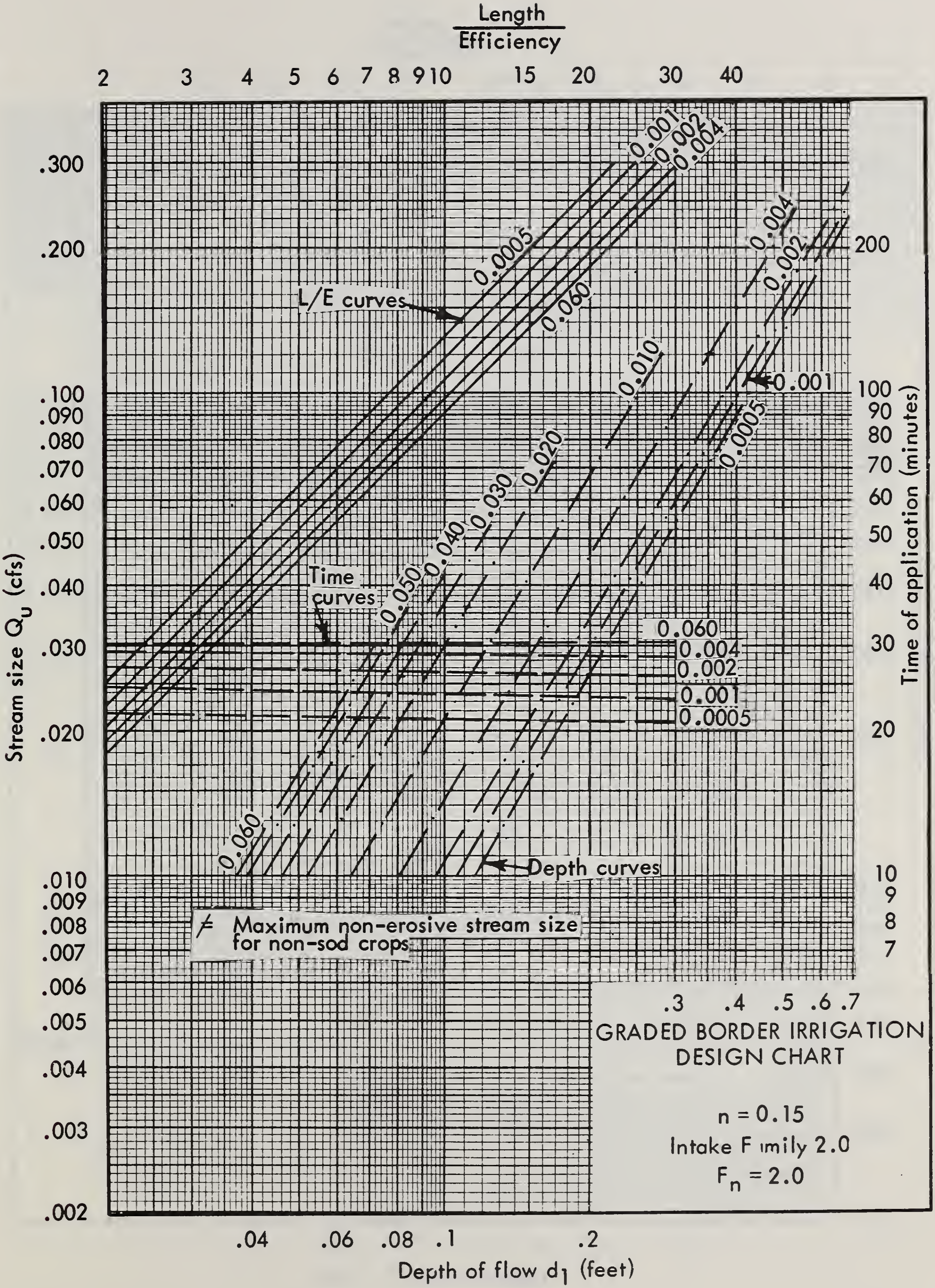


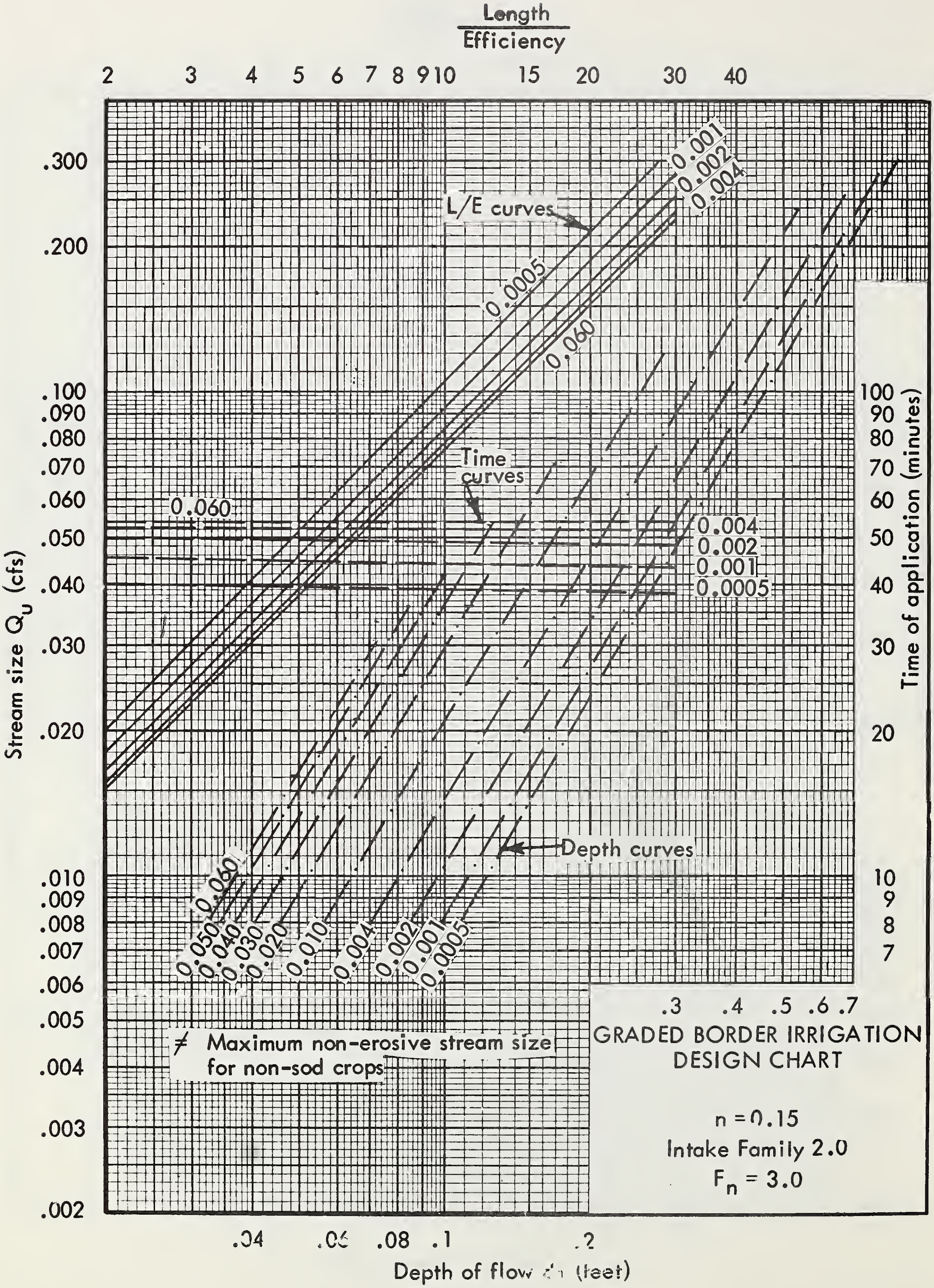
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Time curves
L/E curves
Depth curves
0.0005 0.001 0.002 0.004 0.060
0.060 0.050 0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Stream size Q_u (cfs)
100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 4.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.004
0.002
0.001
Time curves
0.052
0.0005
0.001
0.002
0.004
L/E curves
0.0005
0.052
Depth curves
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
0.052
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 1.5
F_n = 5.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)


Length
Efficiency
2
3
4
5
6
7
8
9
10
15
20
30
40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
0.001
0.002
0.004
0.010
0.0005
0.050
L/E curves
0.004
0.002
0.001
0.0005
0.010
0.020
0.030
0.040
0.050
Depth curves
Time curves
0.050
0.010
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
.04
.06
.08
.1
.2
.3
.4
.5
.6
.7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 1.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
L/E curves
0.0005
0.001
0.002
0.004
0.060
0.010
0.020
0.030
0.040
0.050
Time curves
0.060
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake F imily 2.0
F_n = 2.0

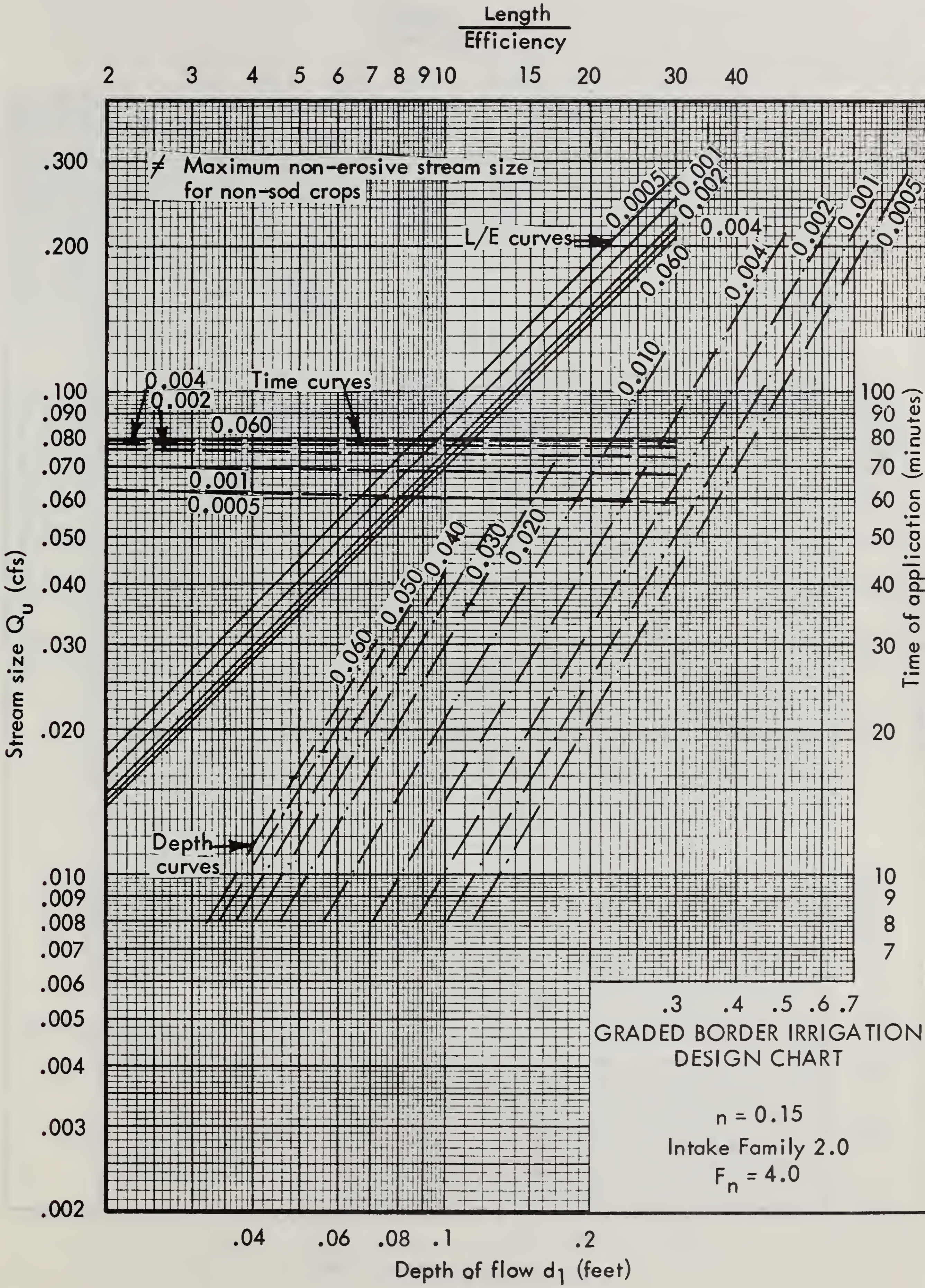


GRADED BORDER IRRIGATION DESIGN CHART

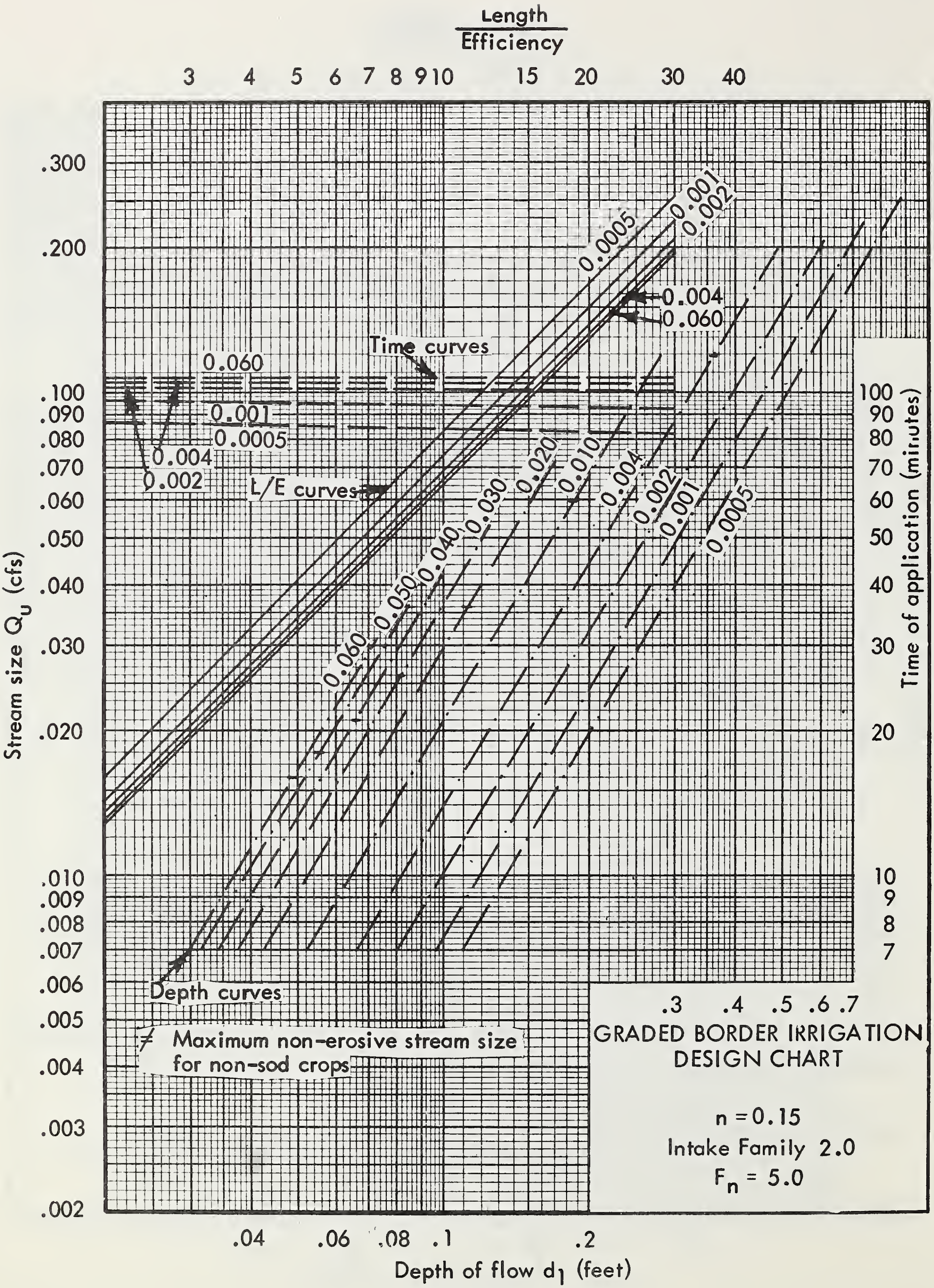
n = 0.15

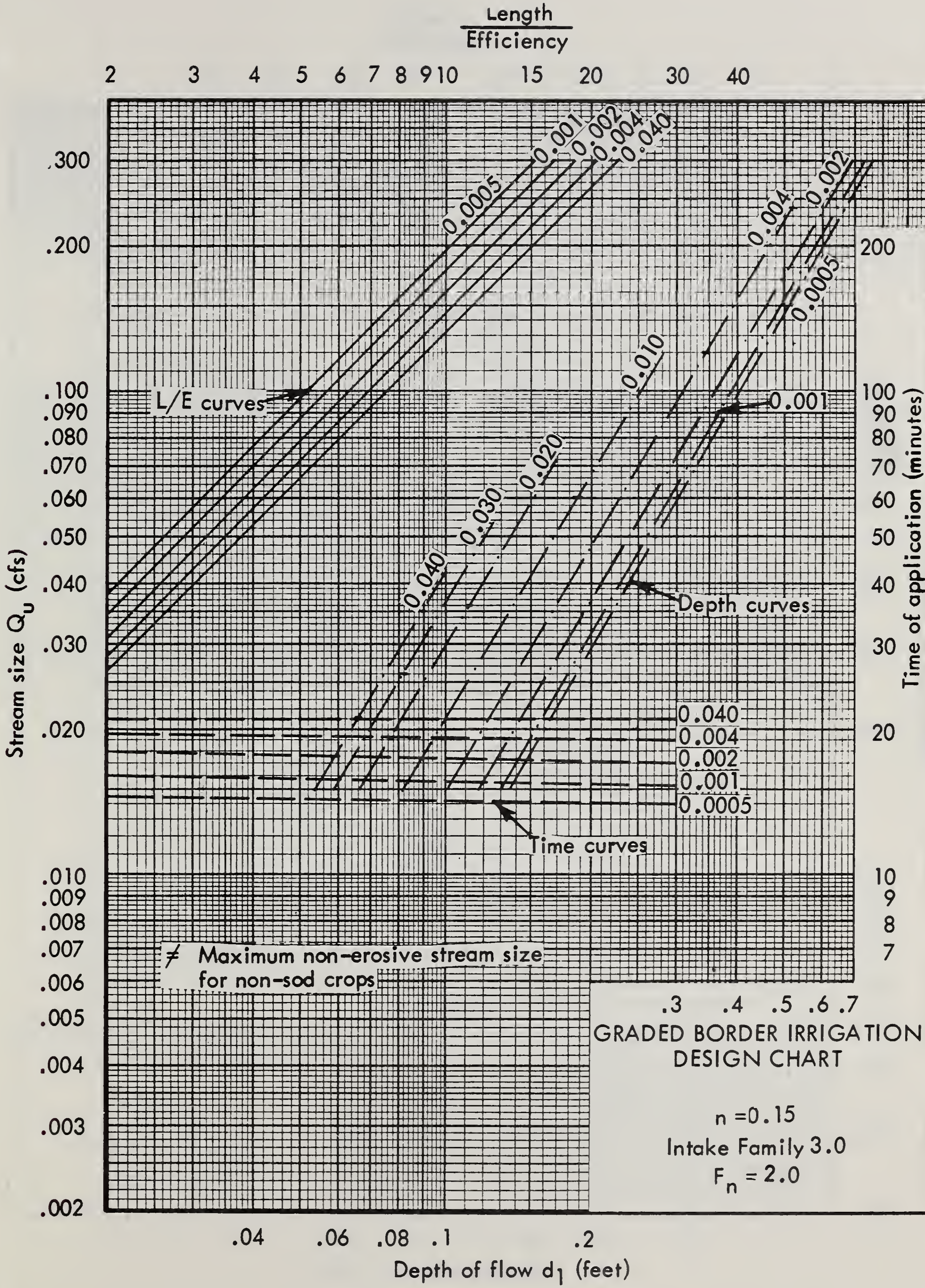
Intake Family 2.0

F_n = 3.0

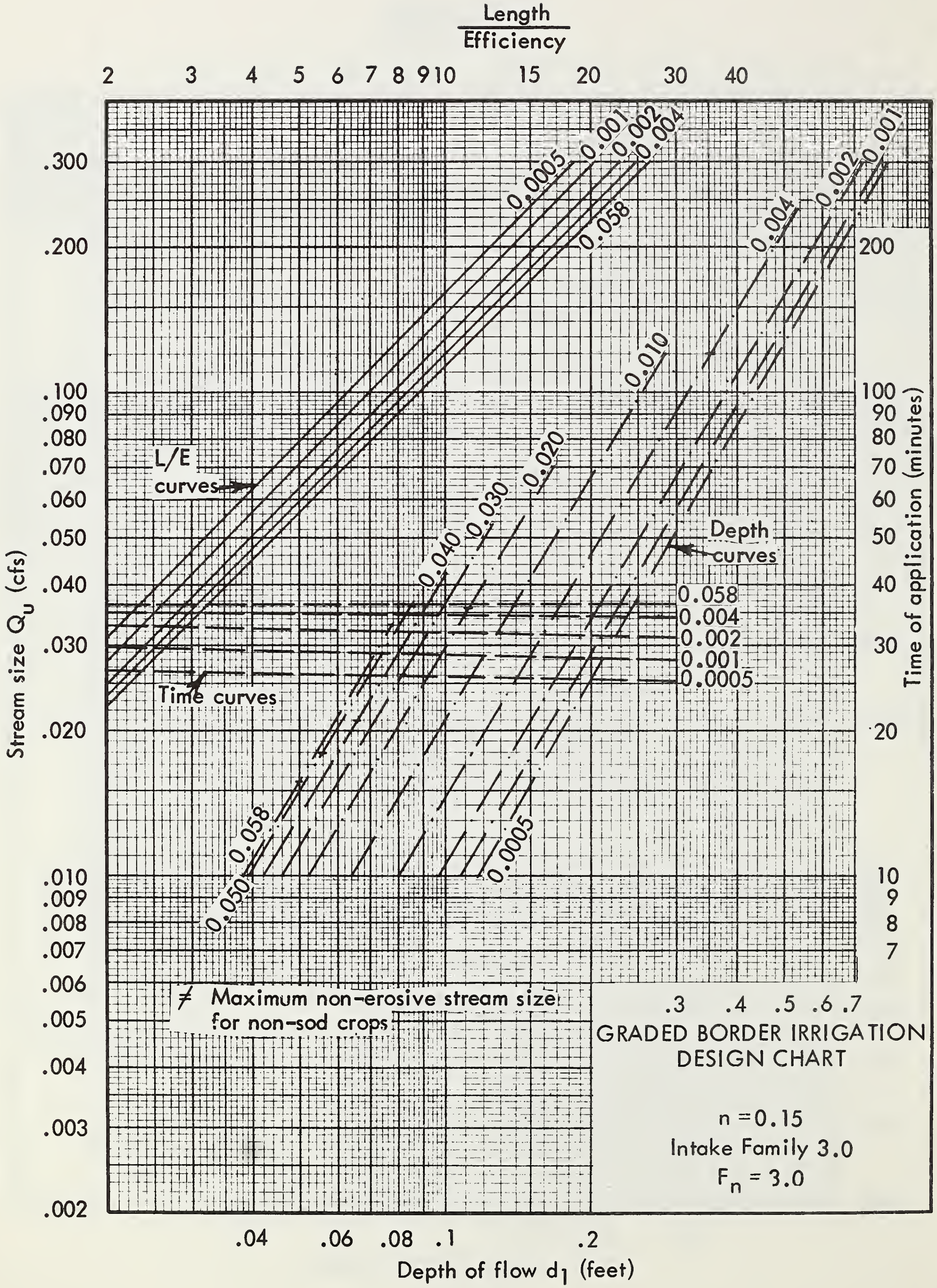


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
L/E curves
0.0005
0.001
0.002
0.004
0.060
0.010
0.020
0.030
0.040
0.050
Time curves
0.004
0.002
0.060
0.001
0.0005
Depth curves
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 4.0

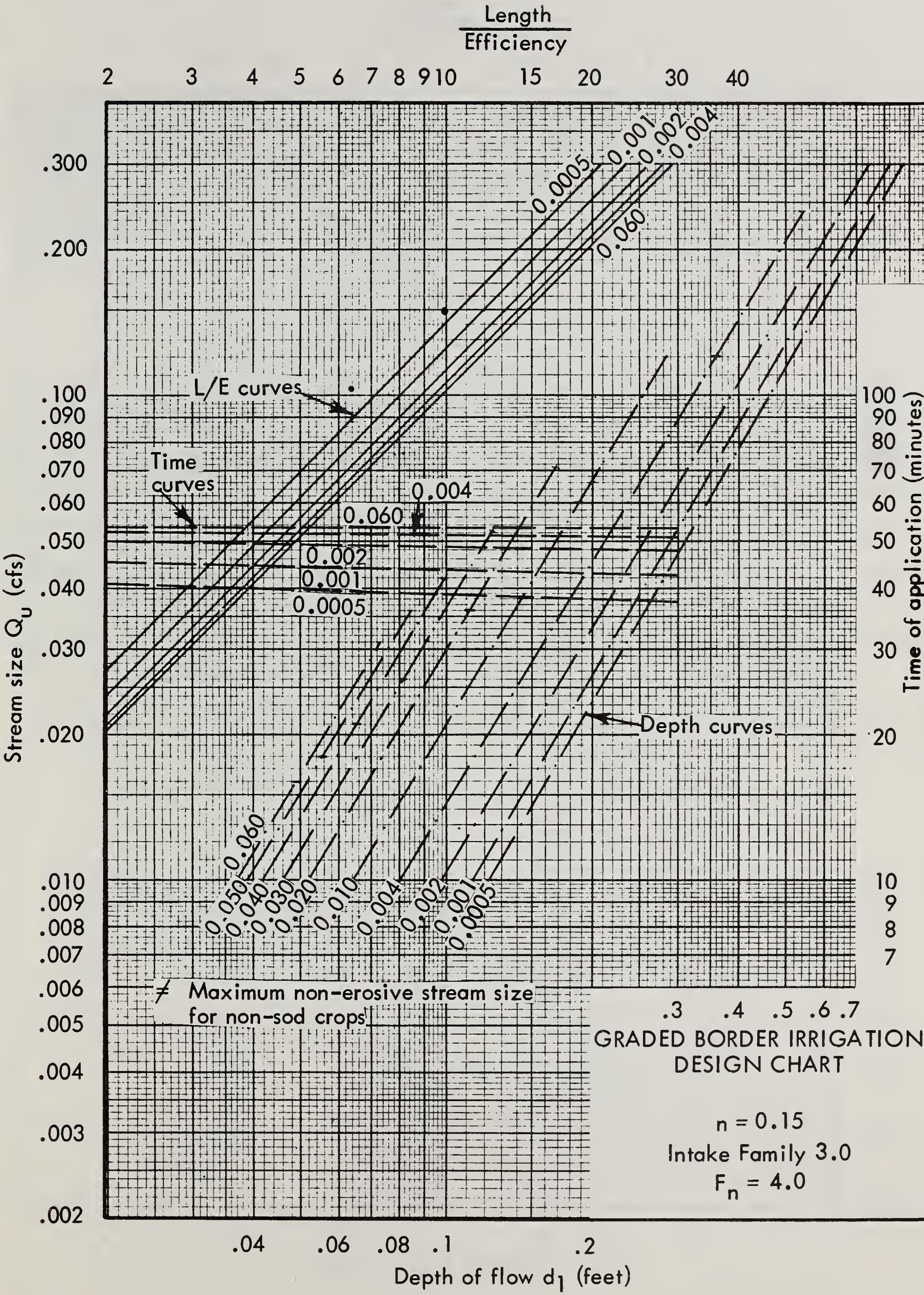

Length
Efficiency
3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
0.0005
0.001
0.002
0.004
0.060
Time curves
0.060
0.001
0.0005
0.004
0.002
L/E curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 2.0
F_n = 5.0



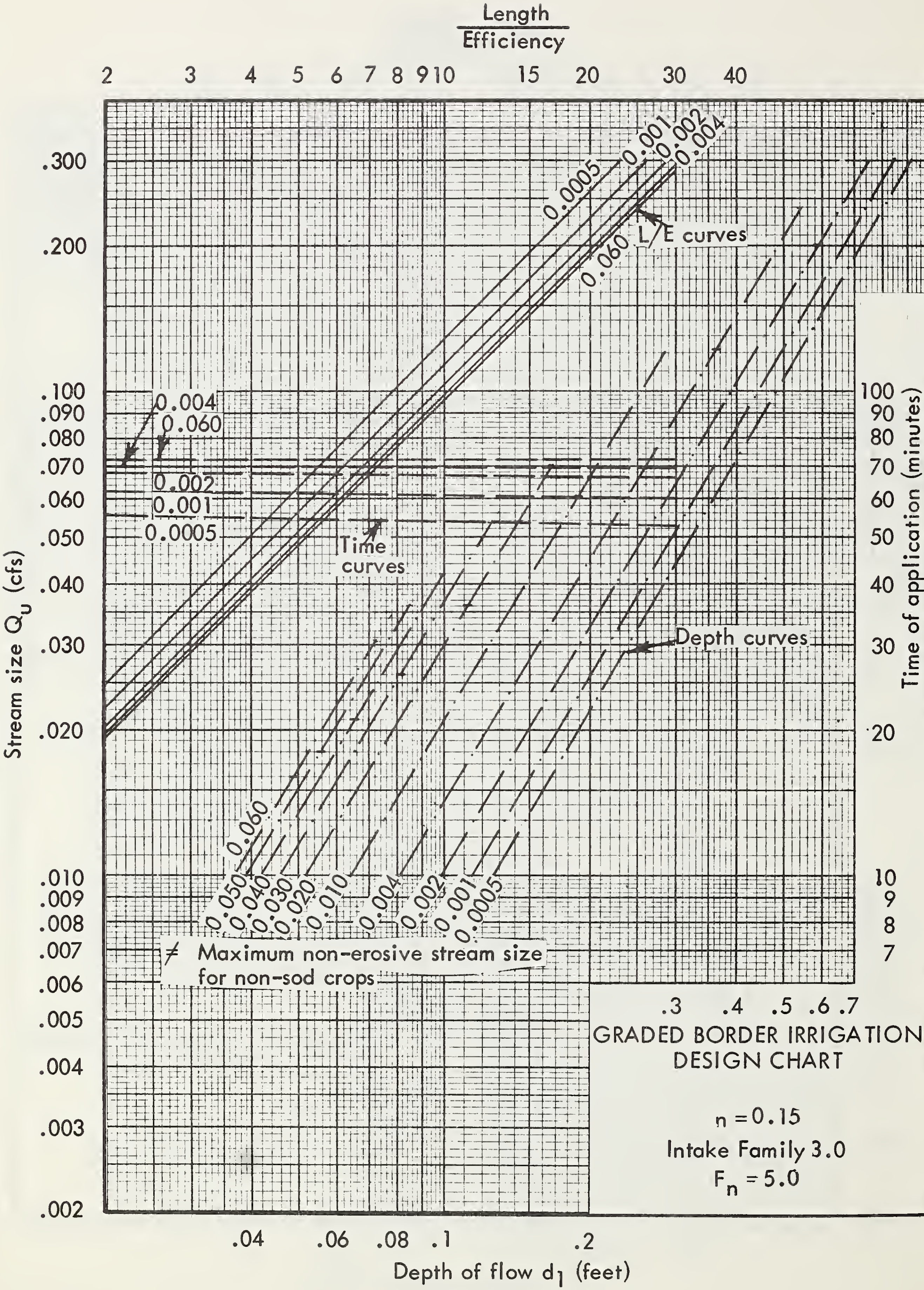
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.0005
0.001
0.002
0.004
0.040
0.010
0.020
0.030
0.040
L/E curves
Depth curves
Time curves
0.040
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n =0.15
Intake Family 3.0
F_n = 2.0



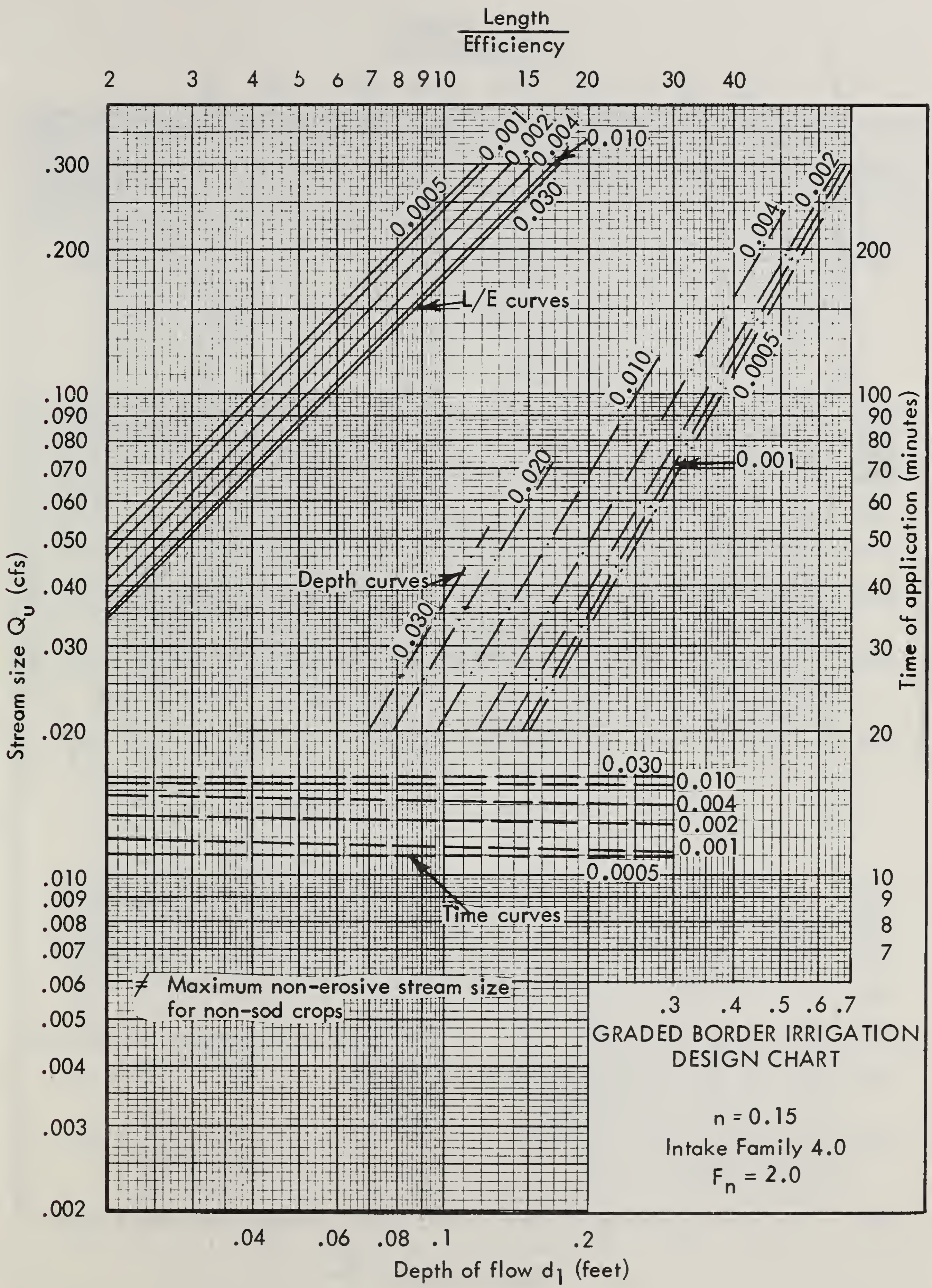
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_U (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
0.0005 0.001 0.002 0.004 0.058
0.004 0.002 0.001
0.010 0.020 0.030 0.040 0.050 0.058 0.0005
L/E curves
Time curves
Depth curves
0.058 0.004 0.002 0.001 0.0005
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 3.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
L/E curves
Time curves
0.0005
0.001
0.002
0.004
0.060
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
Maximum non-erosive stream size for non-sod crops
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 4.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.0005
0.001
0.002
0.004
0.060
L/E curves
0.004
0.060
0.002
0.001
0.0005
Time curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 3.0
F_n = 5.0

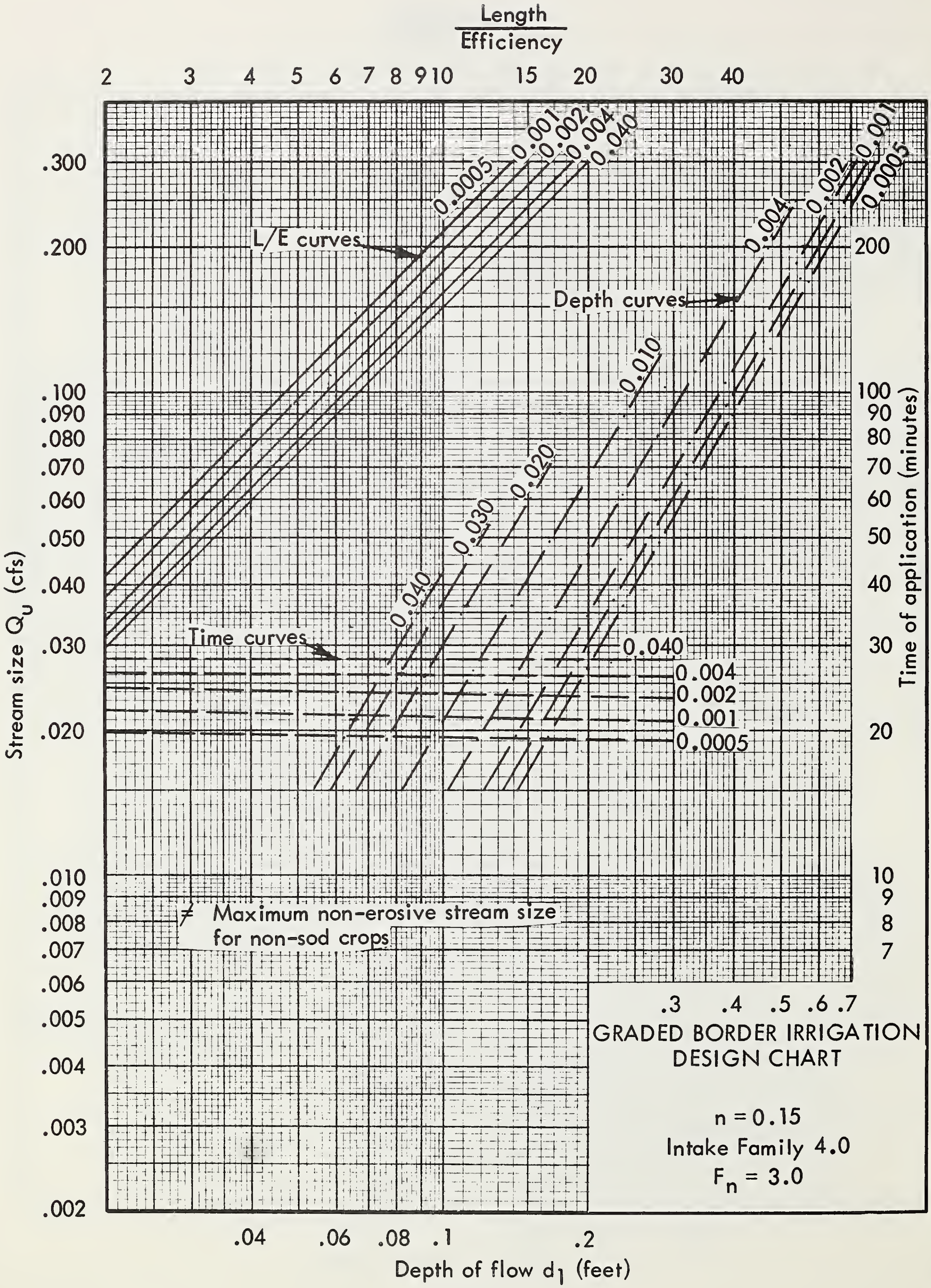


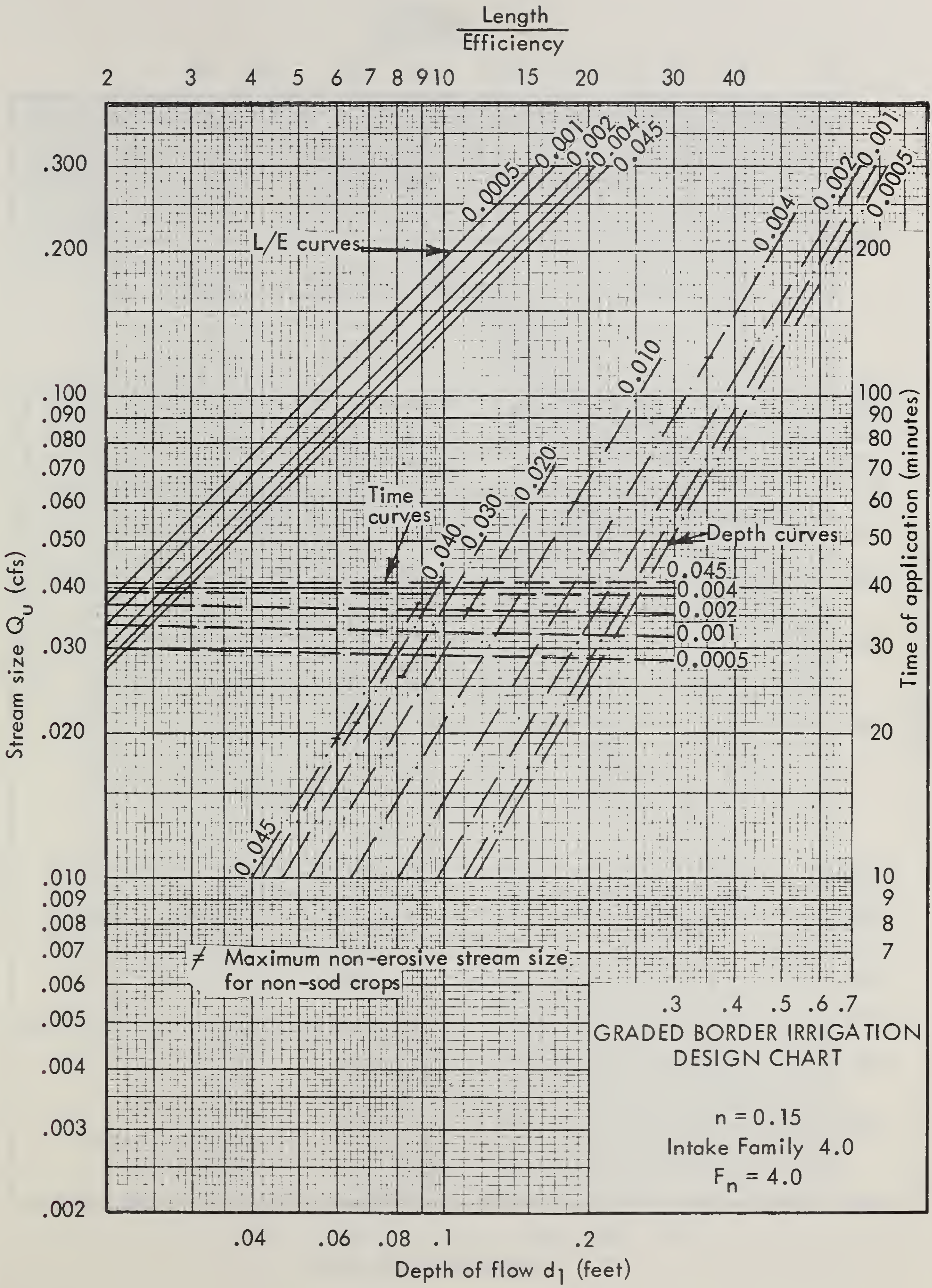
GRADED BORDER IRRIGATION DESIGN CHART

n = 0.15

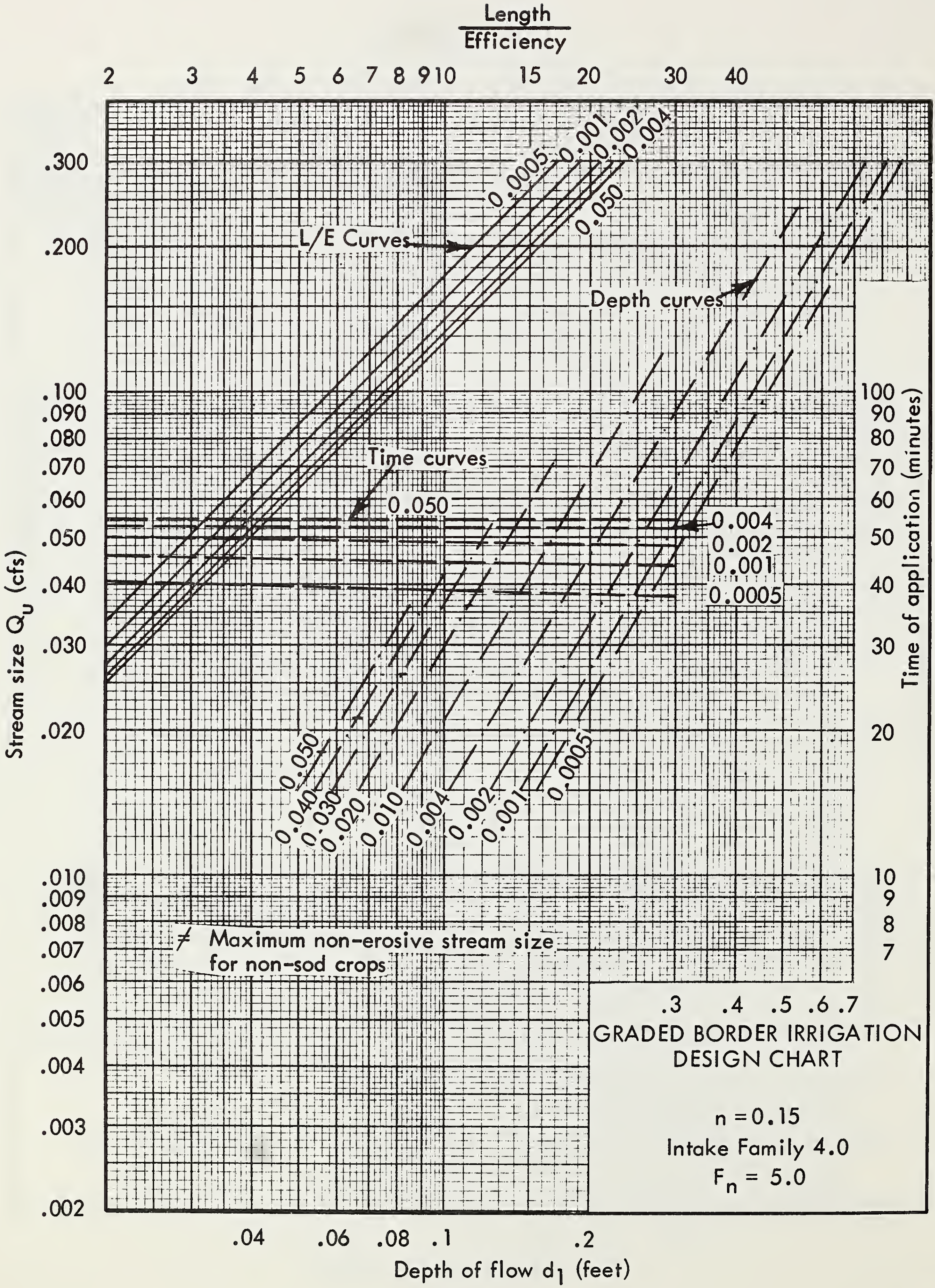
Intake Family 4.0

$F_n = 2.0$

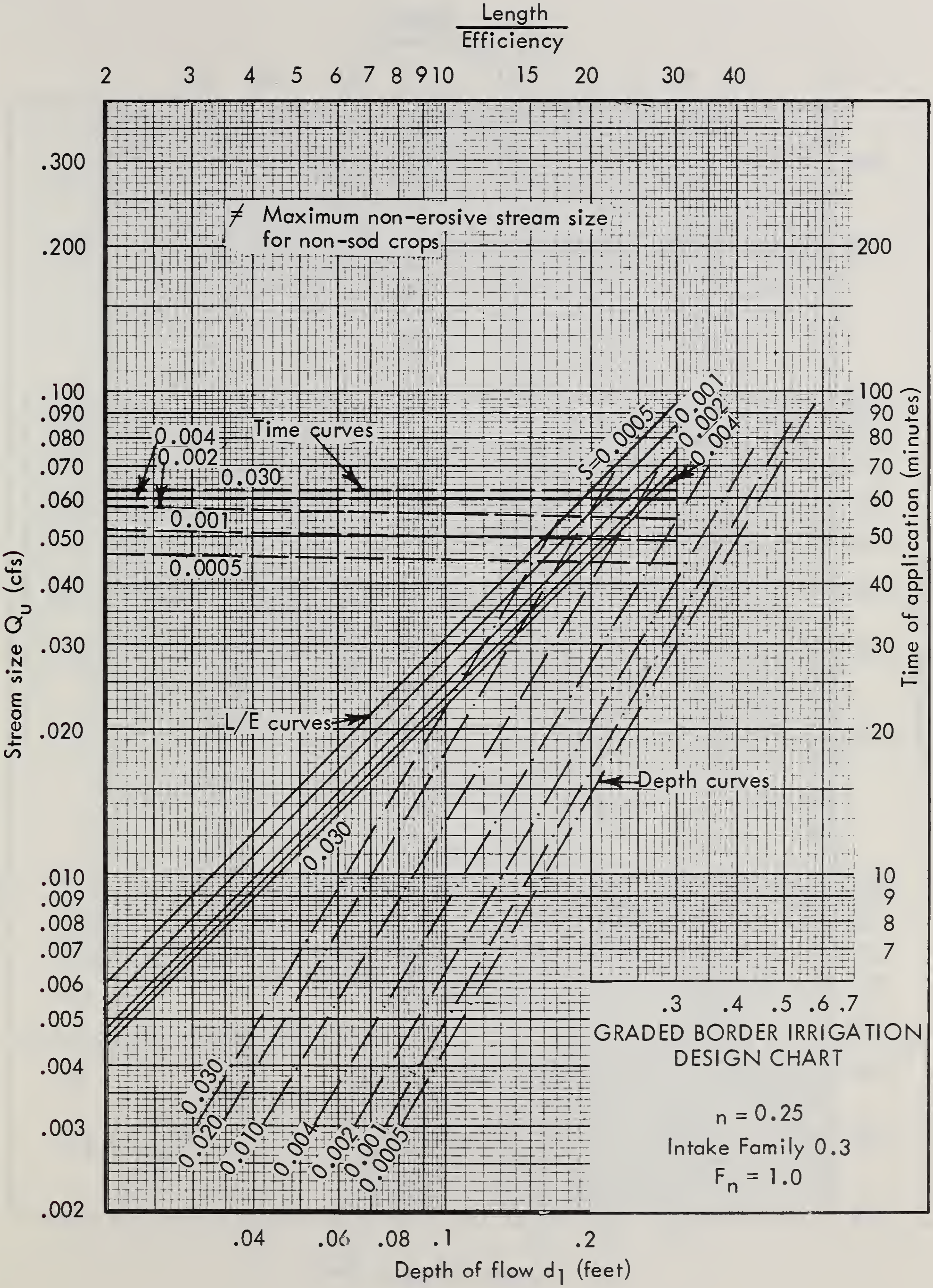

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
200
100
90
80
70
60
50
40
30
20
10
9
8
7
L/E curves
0.0005
0.001
0.002
0.004
0.040
Depth curves
0.004
0.002
0.001
0.0005
0.010
0.020
0.030
0.040
Time curves
0.040
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 3.0



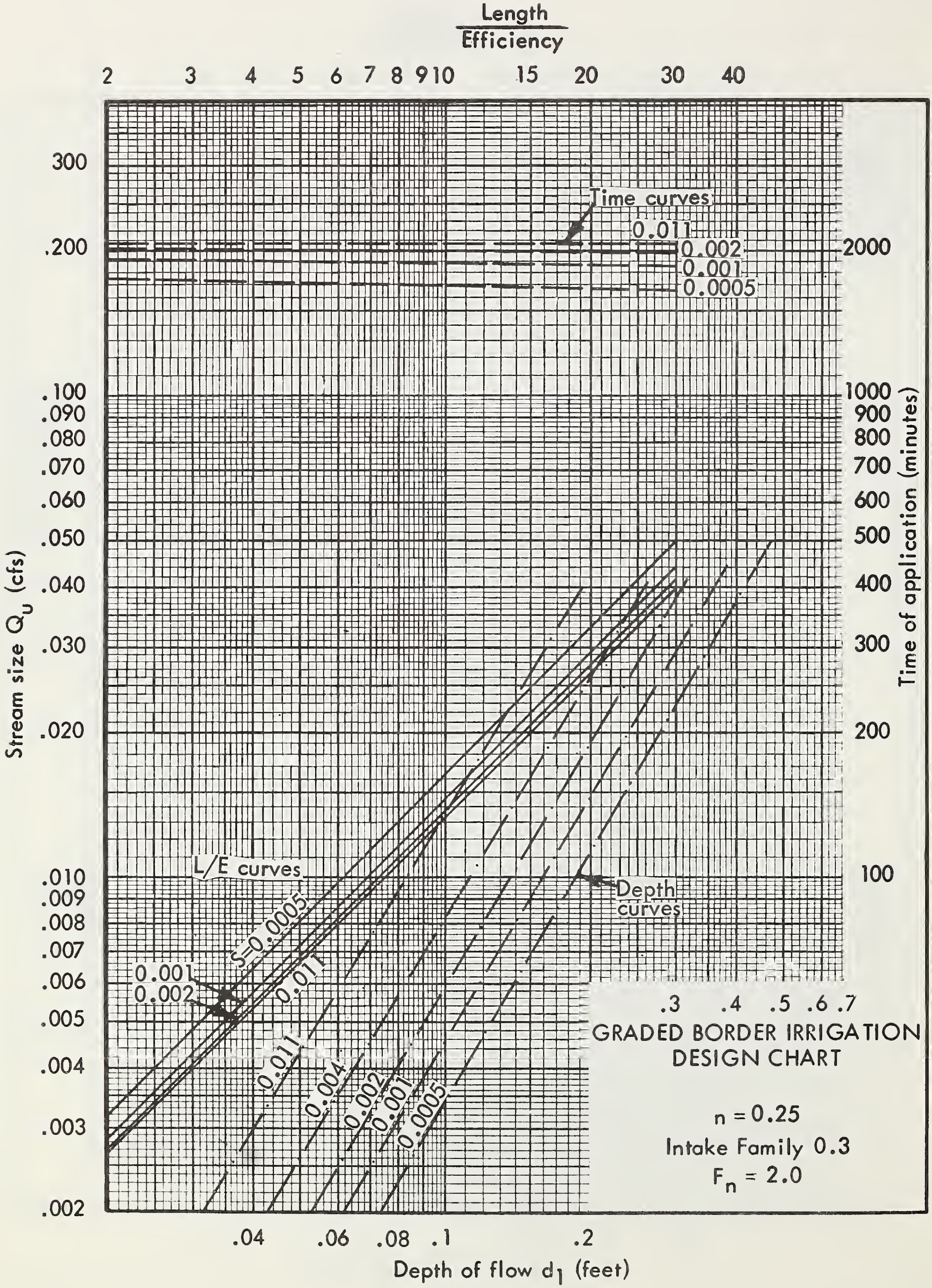
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
L/E curves
0.0005
0.001
0.002
0.004
0.045
0.004
0.002
0.001
0.0005
0.010
0.020
0.030
0.040
Time curves
Depth curves
0.045
0.004
0.002
0.001
0.0005
0.045
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
≠ Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 4.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

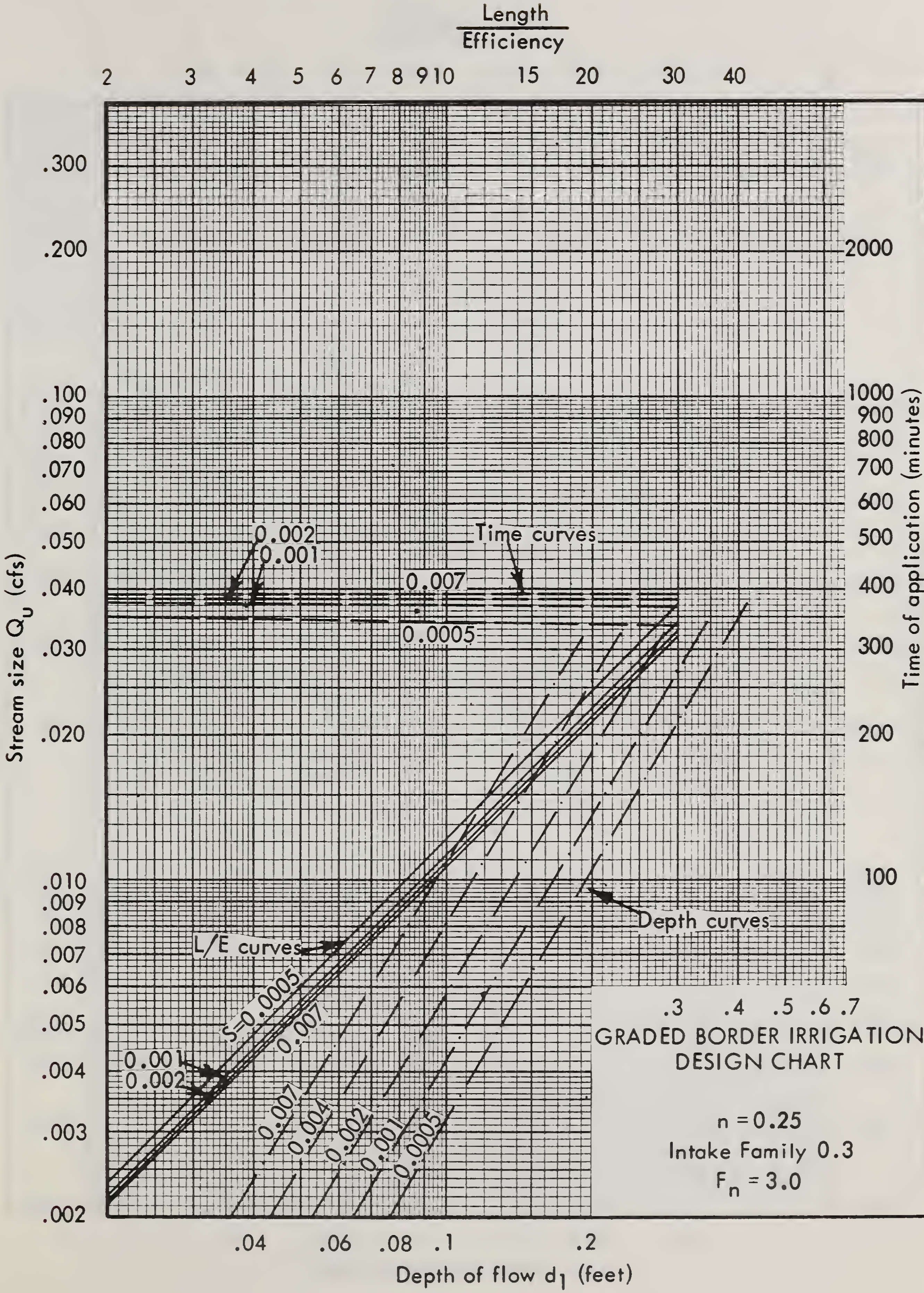


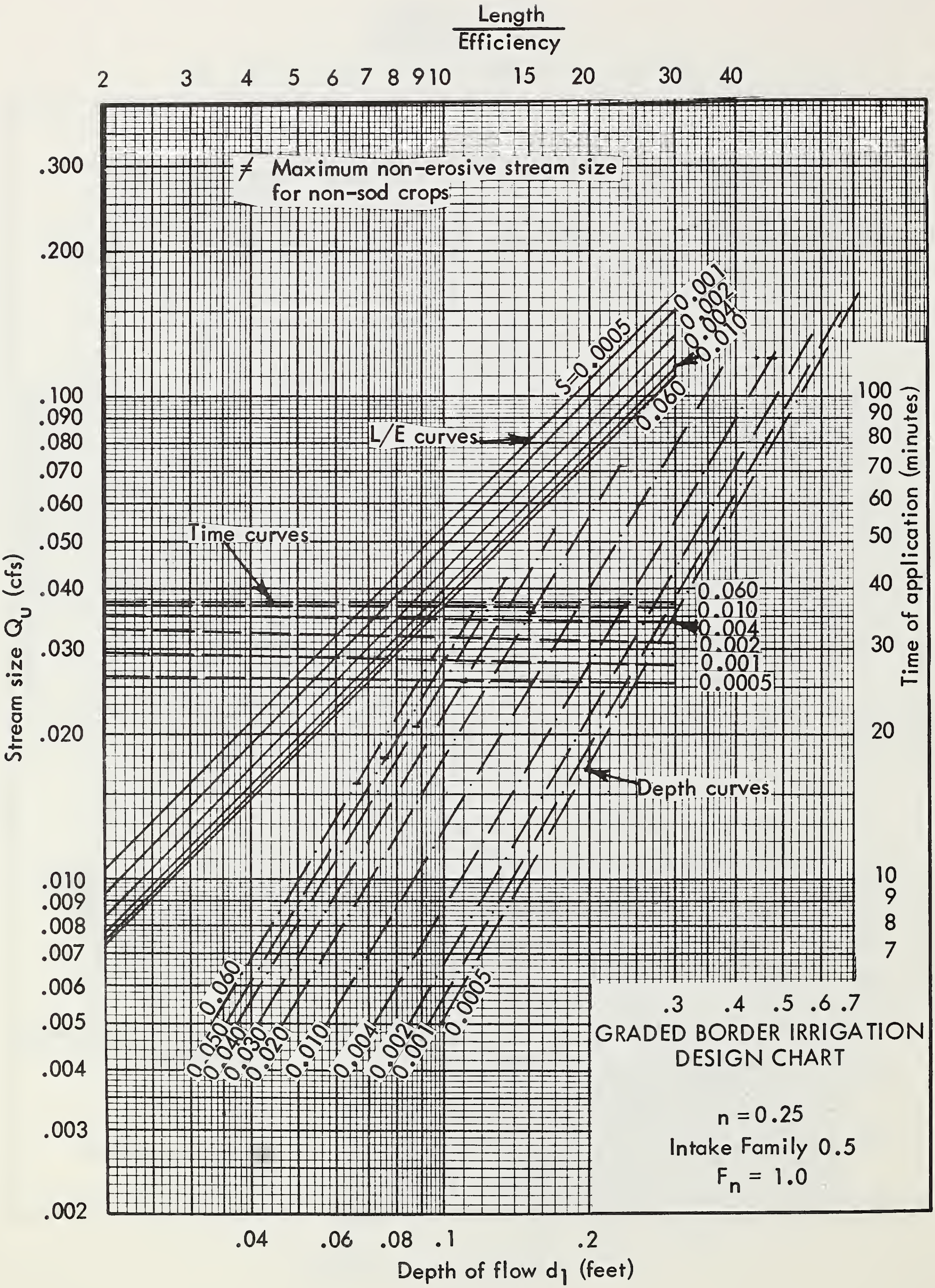
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
0.0005
0.001
0.002
0.004
0.050
L/E Curves
Depth curves
Time curves
0.050
0.004
0.002
0.001
0.0005
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.15
Intake Family 4.0
F_n = 5.0



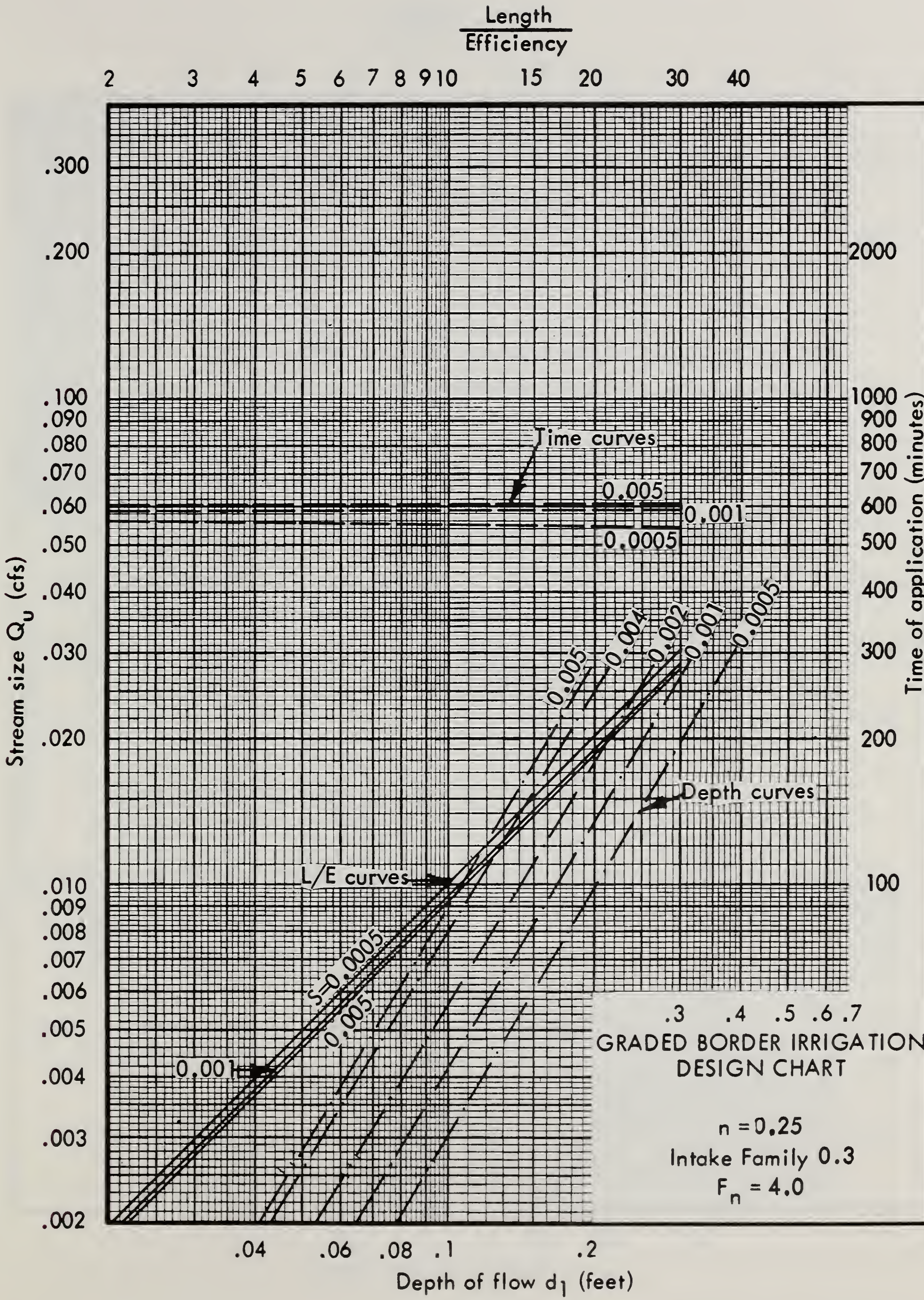
Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
≠ Maximum non-erosive stream size for non-sod crops
Time curves
L/E curves
Depth curves
S=0.0005
0.001
0.002
0.004
0.030
0.020
0.010
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 1.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Time curves
0.011
0.002
0.001
0.0005
Stream size Q_u (cfs)
300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
2000
1000
900
800
700
600
500
400
300
200
100
Time of application (minutes)
L/E curves
S=0.0005
0.001
0.002
0.011
Depth curves
0.011
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 2.0

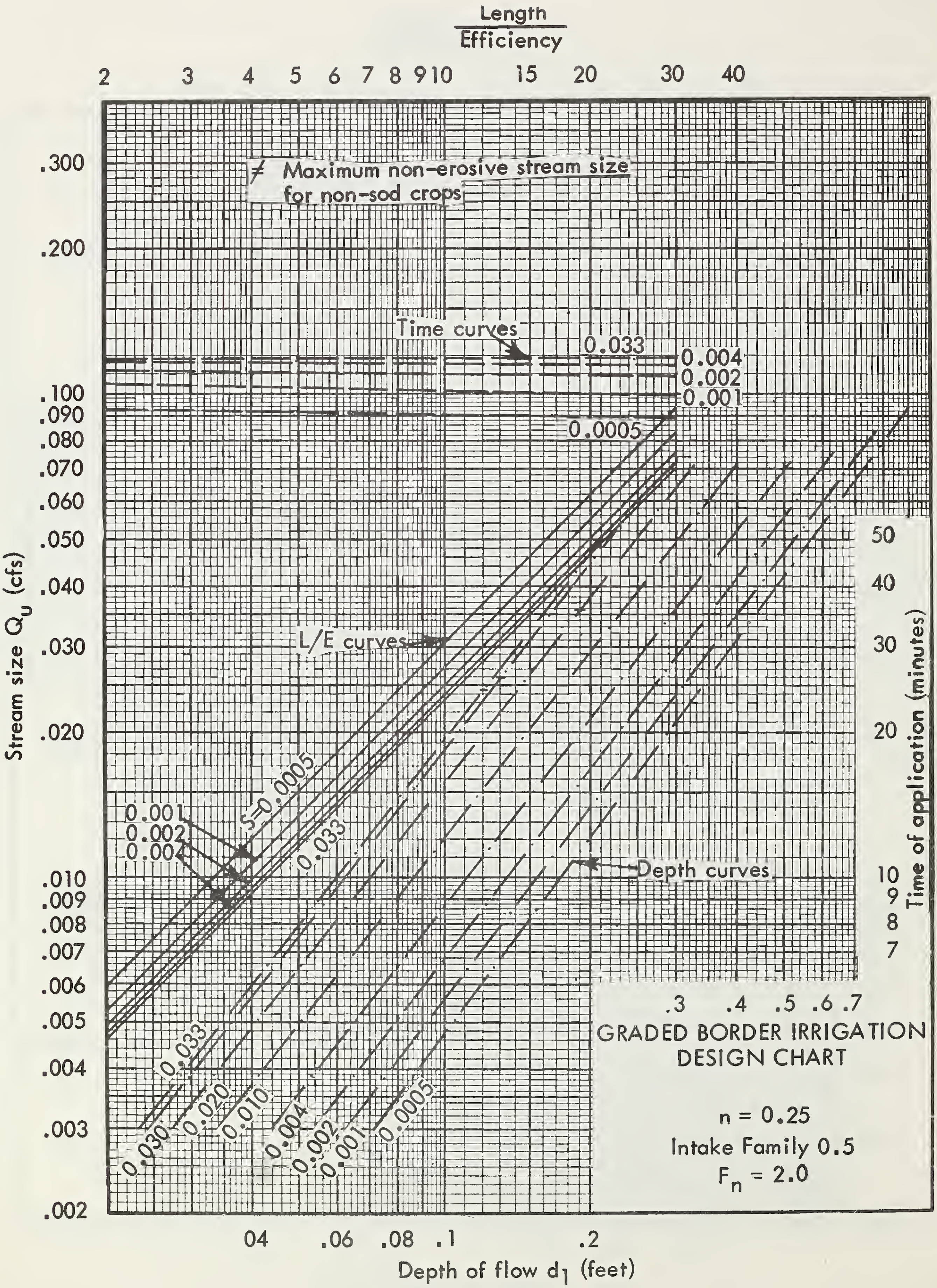

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
2000
1000
900
800
700
600
500
400
300
200
100
0.002
0.001
Time curves
0.007
0.0005
L/E curves
S=0.0005
0.007
0.001
0.002
0.007
0.004
0.002
0.001
0.0005
Depth curves
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 3.0

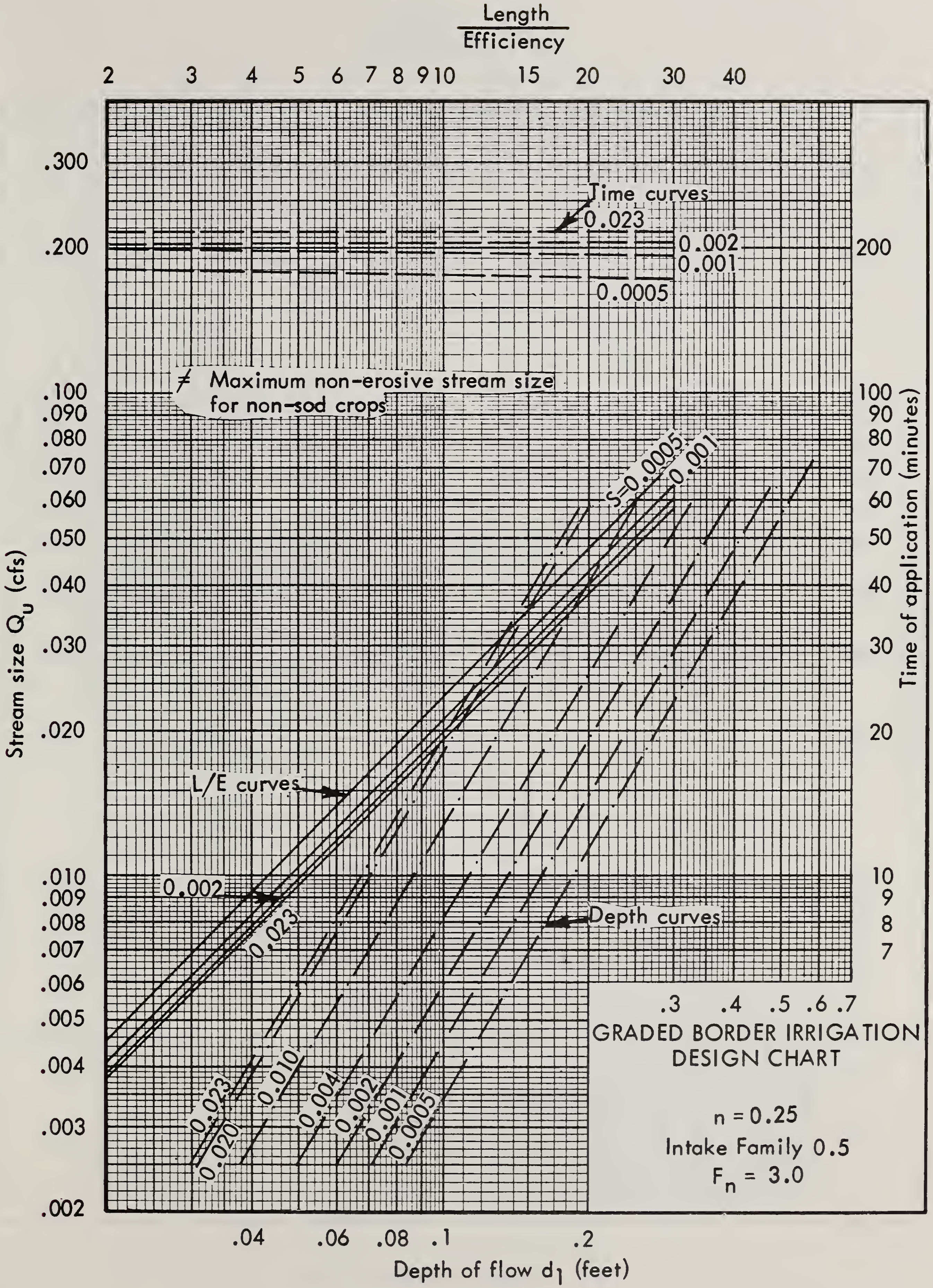


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
≠ Maximum non-erosive stream size
for non-sod crops
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
S=0.0005
0.001
0.002
0.004
0.010
0.060
L/E curves
Time curves
0.060
0.010
0.004
0.002
0.001
0.0005
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 1.0

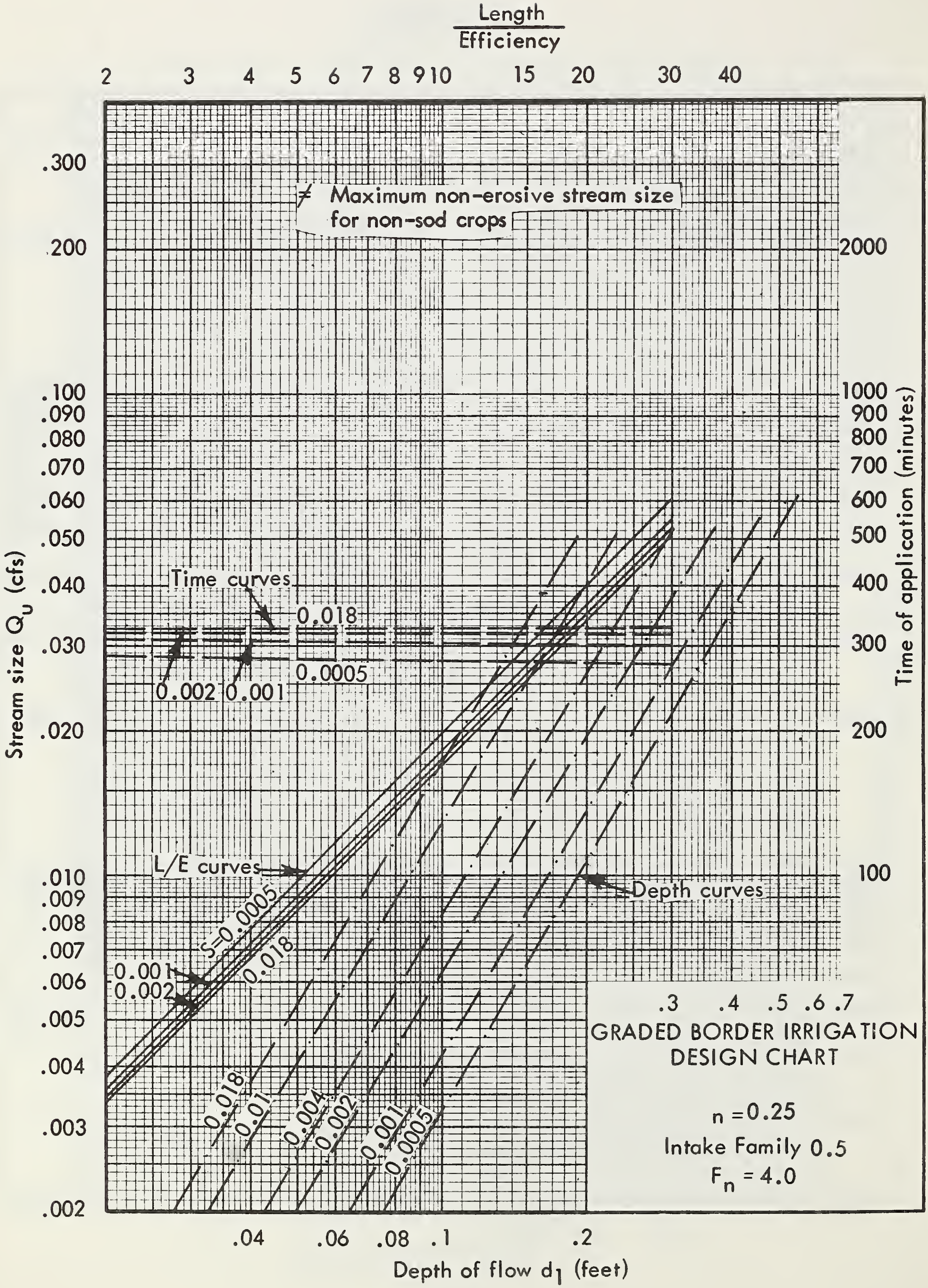


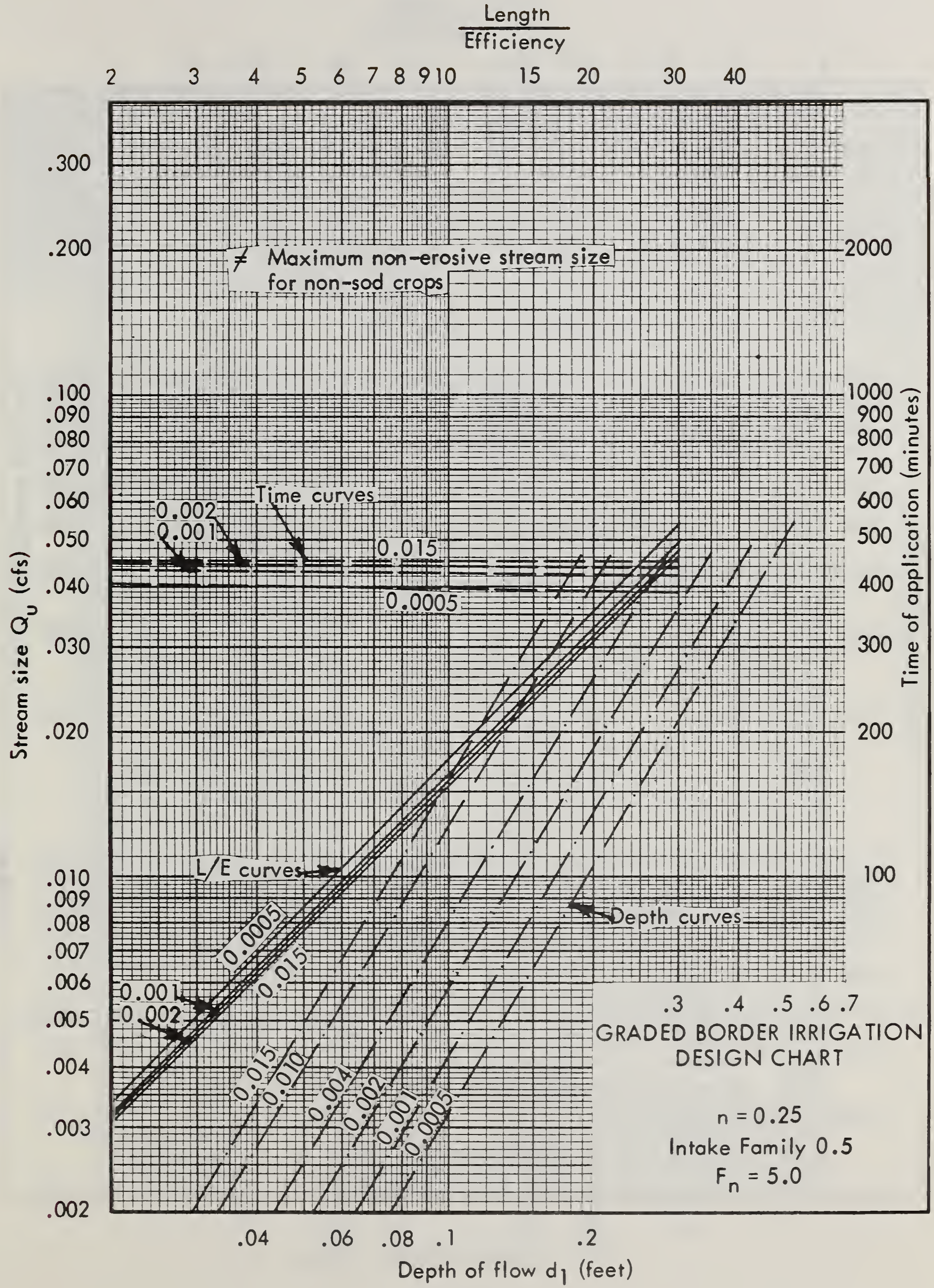
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
2000
1000
900
800
700
600
500
400
300
200
100
Time of application (minutes)
Time curves
0.005
0.001
0.0005
0.005
0.004
0.002
0.001
0.0005
Depth curves
L/E curves
S=0.0005
0.005
0.001
.04 .06 .08 .1 .2
.3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 0.3
F_n = 4.0

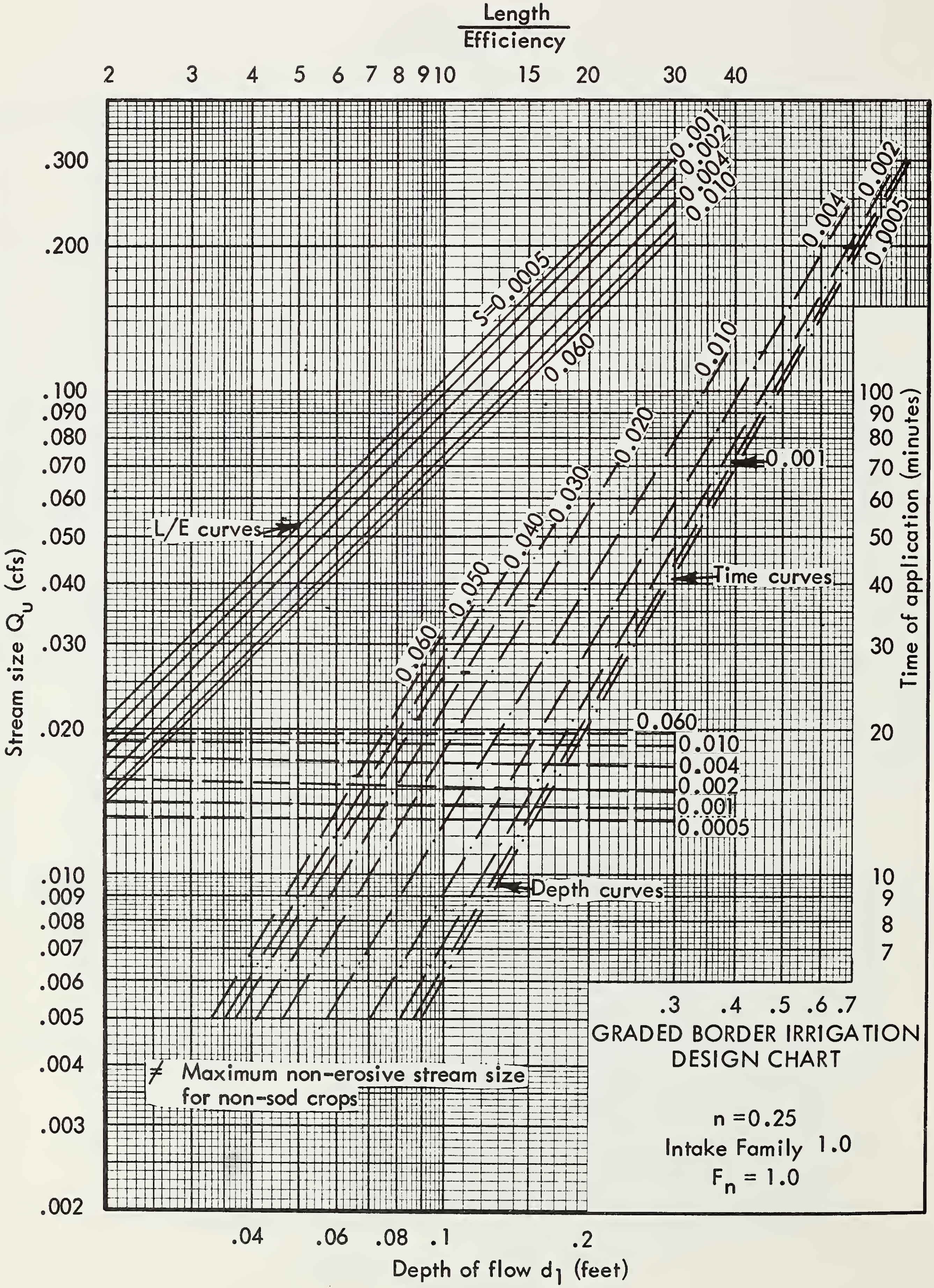

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
≠ Maximum non-erosive stream size for non-sod crops
Time curves
0.033
0.004
0.002
0.001
0.0005
L/E curves
S=0.0005
0.001
0.002
0.004
0.033
Depth curves
0.033
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
50 40 30 20 10 9 8 7
04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 2.0

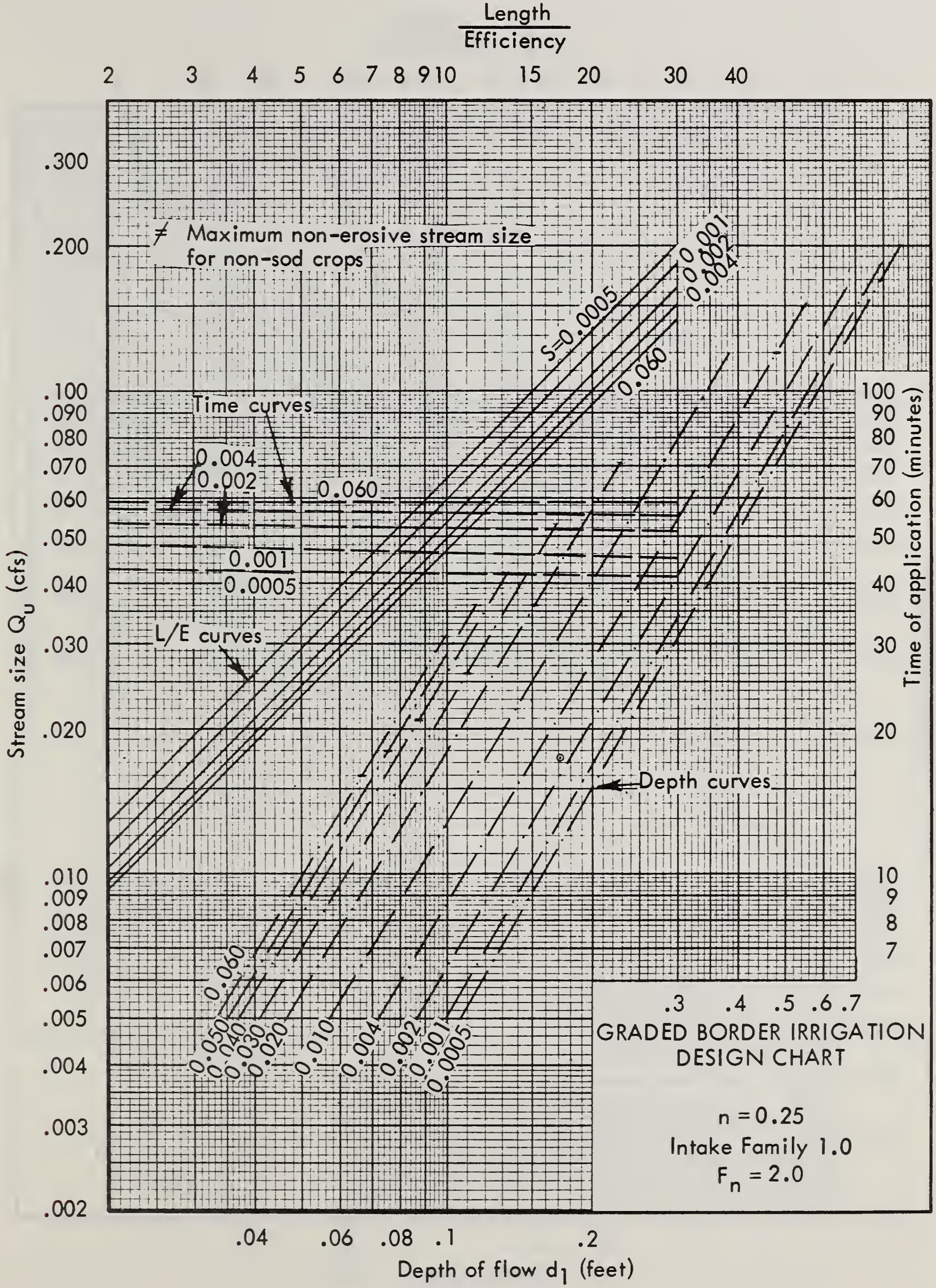


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Time curves
0.023
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
S=0.0005
0.001
L/E curves
0.002
0.023
Depth curves
0.023
0.020
0.010
0.004
0.002
0.001
0.0005
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Stream size Q_u (cfs)
200 100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 3.0

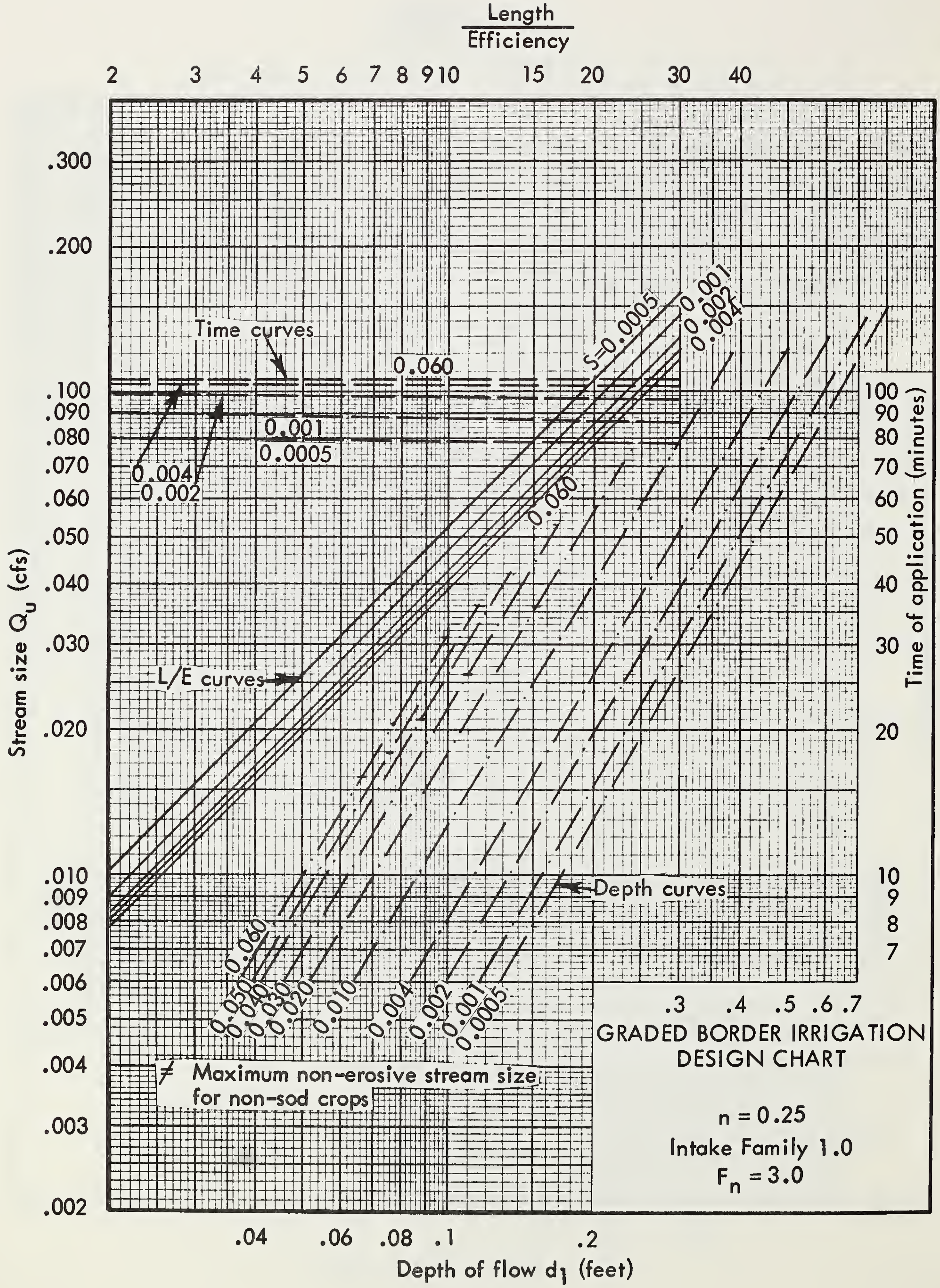

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
2000
1000
900
800
700
600
500
400
300
200
100
Time curves
0.018
0.0005
0.002
0.001
L/E curves
S=0.0005
0.018
0.001
0.002
Depth curves
0.018
0.01
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 4.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

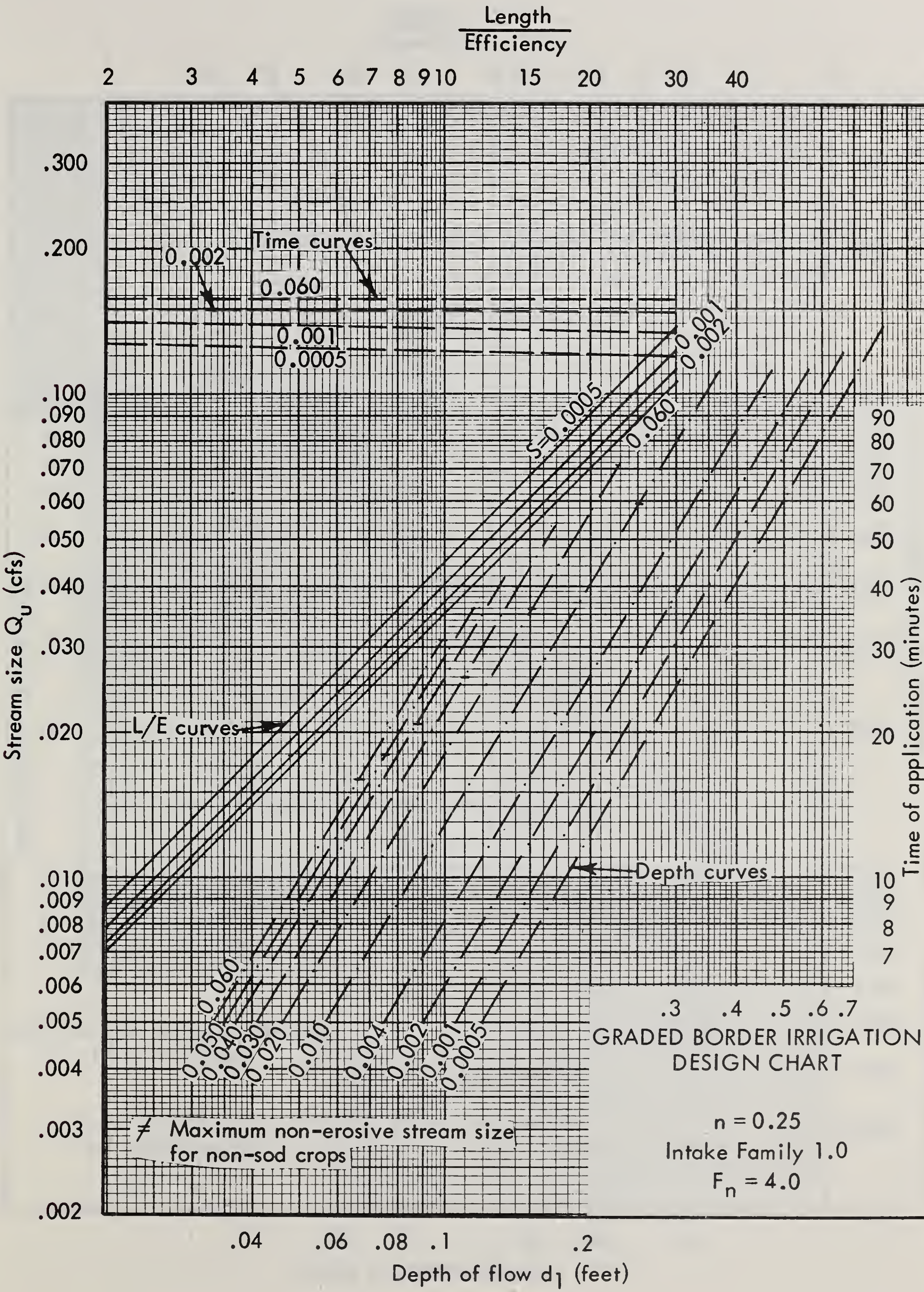

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
2000
1000
900
800
700
600
500
400
300
200
100
Maximum non-erosive stream size for non-sod crops
Time curves
0.002
0.001
0.015
0.0005
L/E curves
0.0005
0.015
0.001
0.002
Depth curves
0.015
0.010
0.004
0.002
0.001
0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 0.5
F_n = 5.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005
0.001
0.002
0.004
0.010
0.060
0.004
0.002
0.0005
0.010
0.020
0.030
0.040
0.050
0.060
0.001
L/E curves
Time curves
0.060
0.010
0.004
0.002
0.001
0.0005
Depth curves
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 1.0
F_n = 1.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Maximum non-erosive stream size for non-sod crops
Time curves
0.004
0.002
0.060
0.001
0.0005
L/E curves
S=0.0005
0.001
0.002
0.004
0.060
Depth curves
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
0.060 0.050 0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
F_n = 2.0


Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
Time curves
0.060
0.001
0.0005
0.004
0.002
S=0.0005
0.001
0.002
0.004
0.060
L/E curves
Depth curves
0.060 0.050 0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
≠ Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
F_n = 3.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

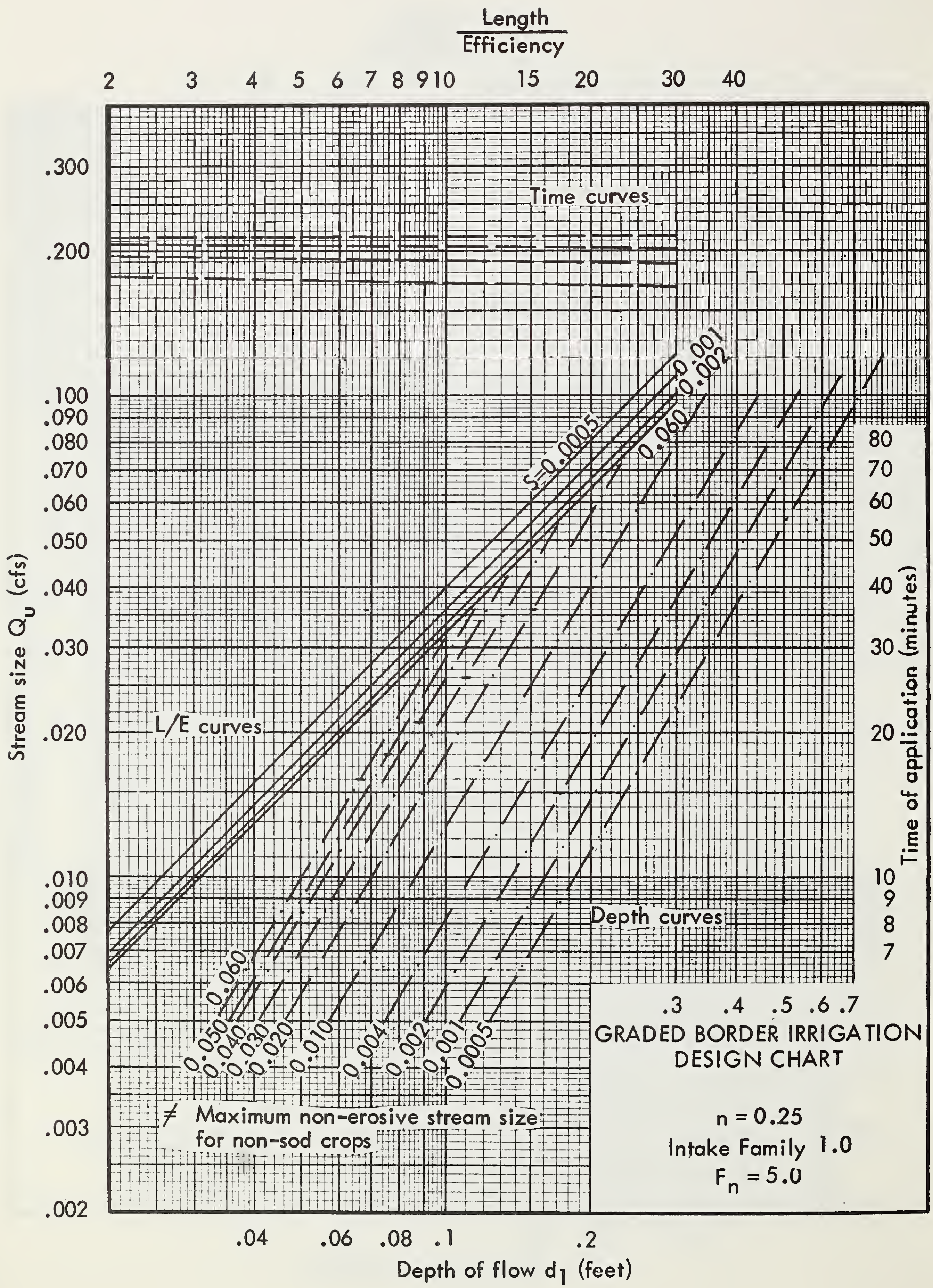


GRADED BORDER IRRIGATION DESIGN CHART

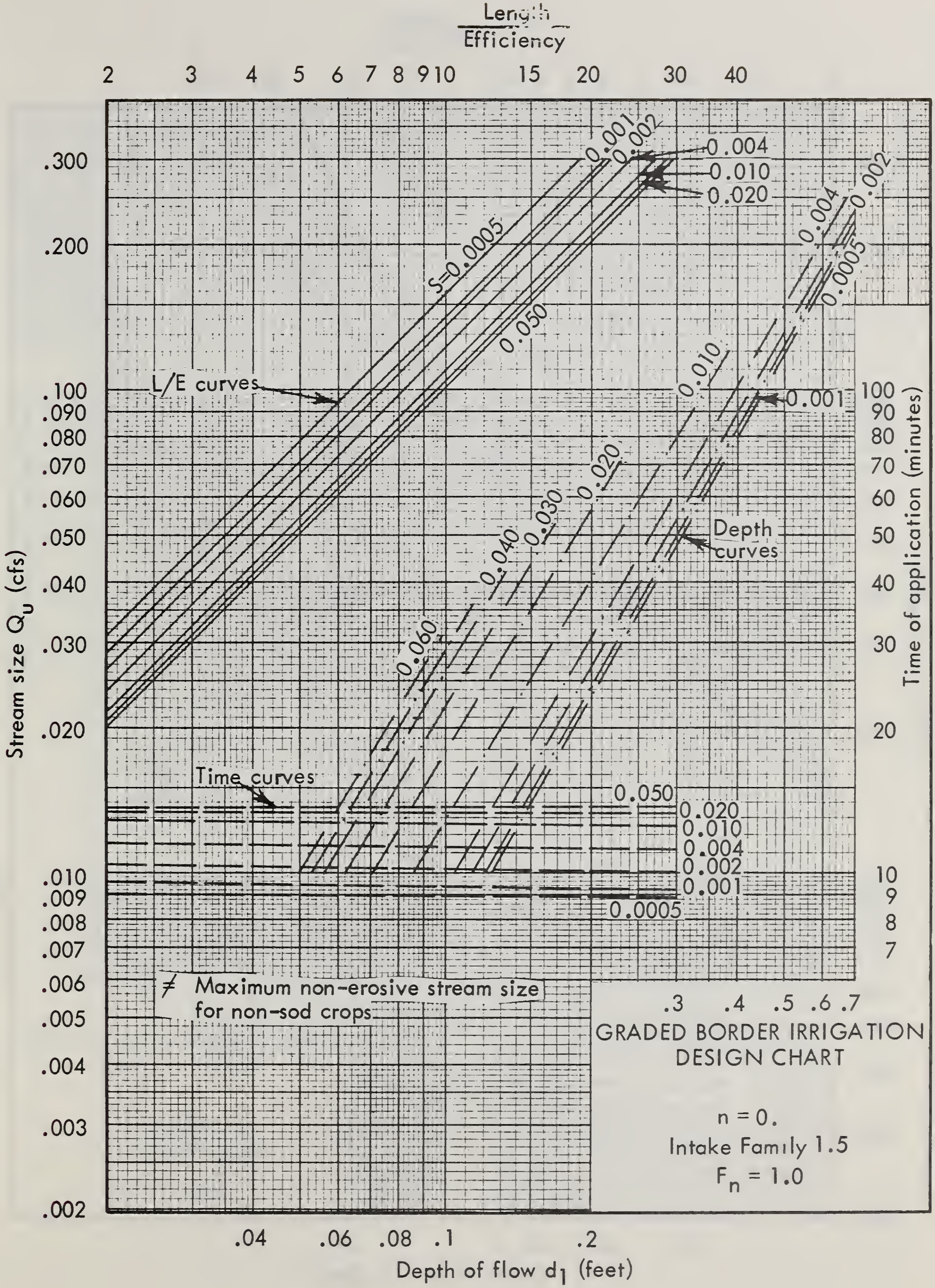
n = 0.25

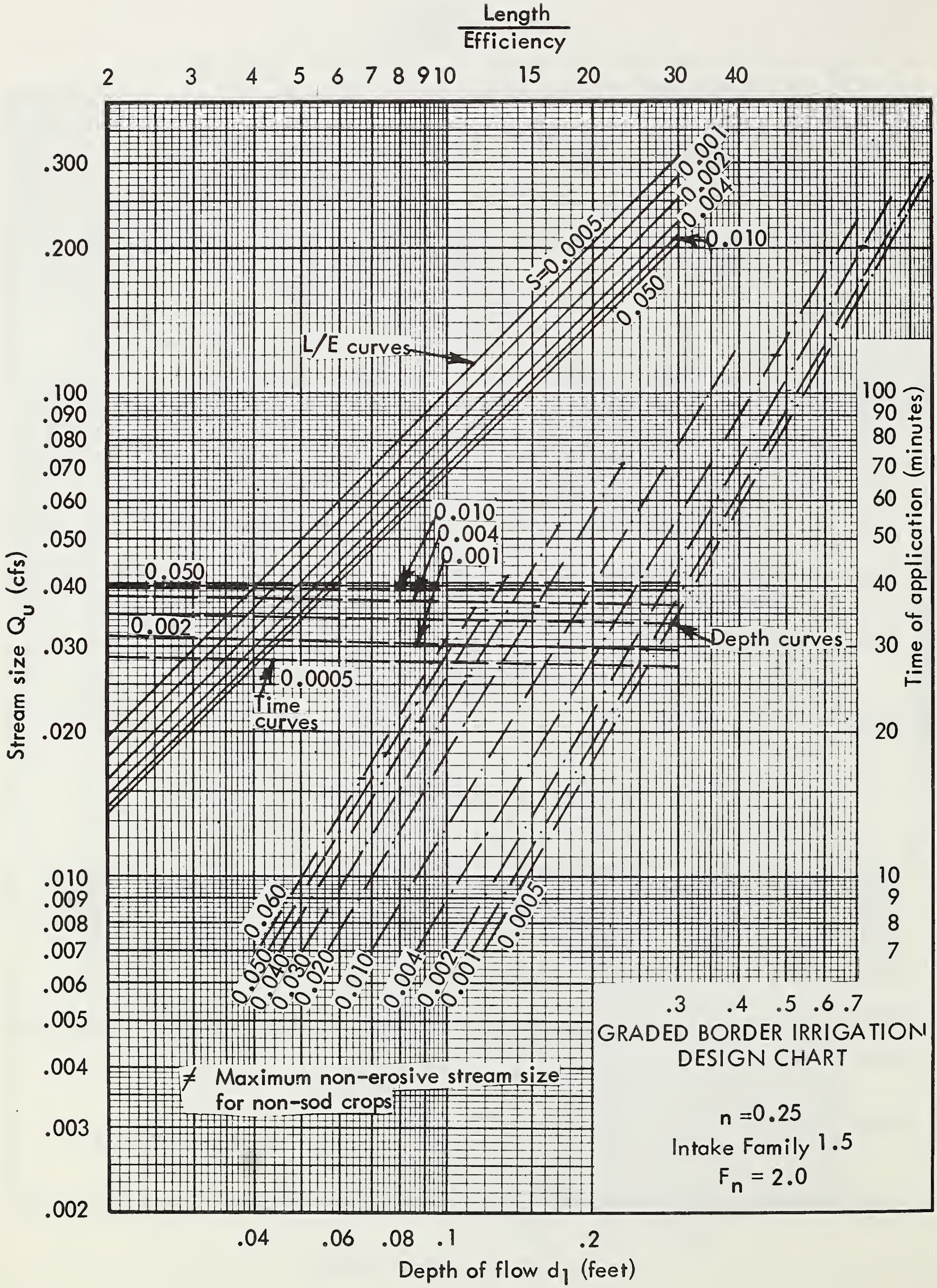
Intake Family 1.0

F_n = 4.0

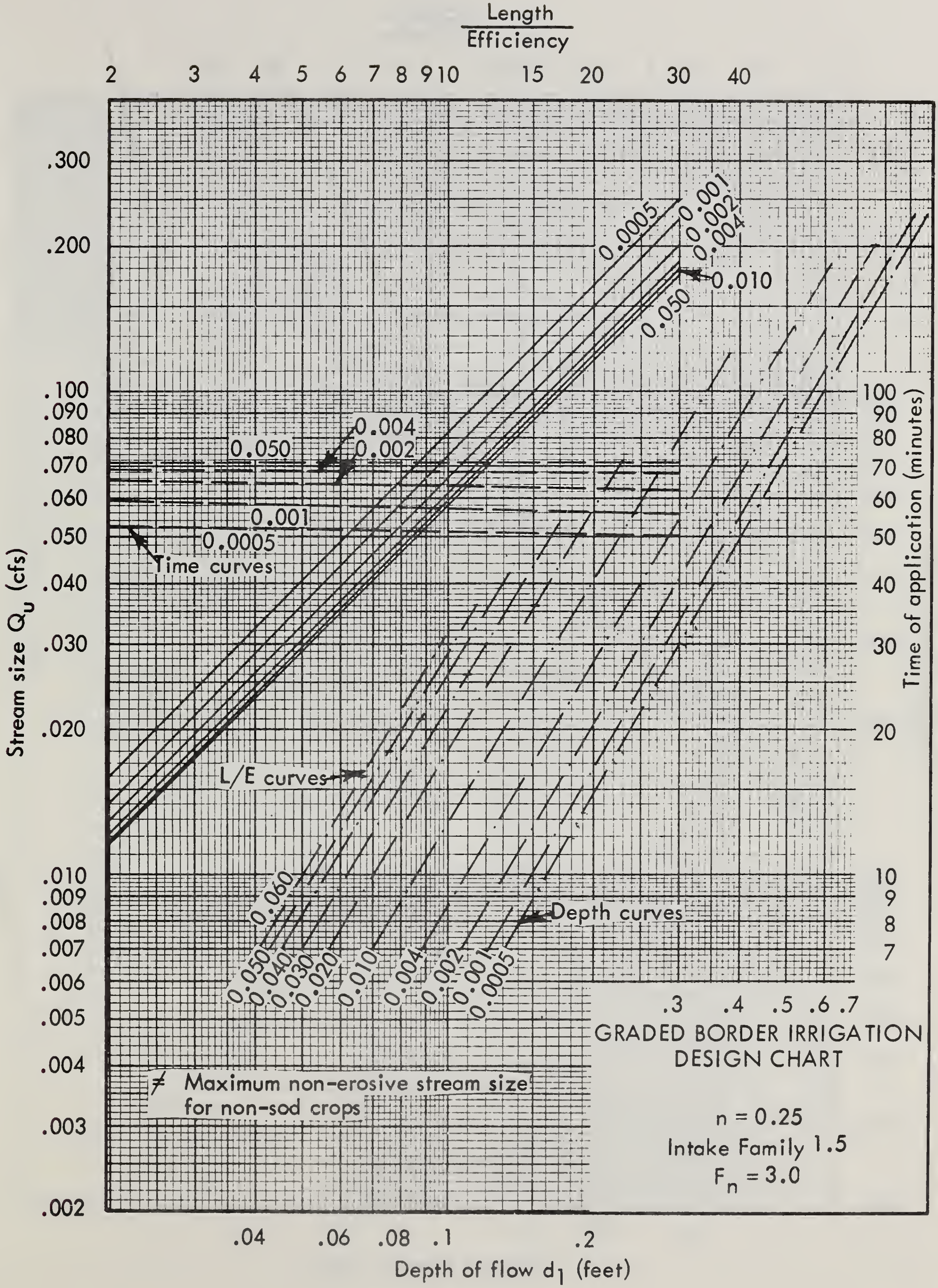


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Time curves
S=0.0005
0.001
0.002
0.060
L/E curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Stream size Q_u (cfs)
80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 1.0
F_n = 5.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005
0.001
0.002
0.004
0.010
0.020
0.050
L/E curves
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
0.060
0.040
0.030
0.020
0.010
0.004
0.002
0.0005
0.001
Depth curves
Time curves
0.050
0.020
0.010
0.004
0.002
0.001
0.0005
Time of application (minutes)
100
90
80
70
60
50
40
30
20
10
9
8
7
≠ Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.
Intake Family 1.5
F_n = 1.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

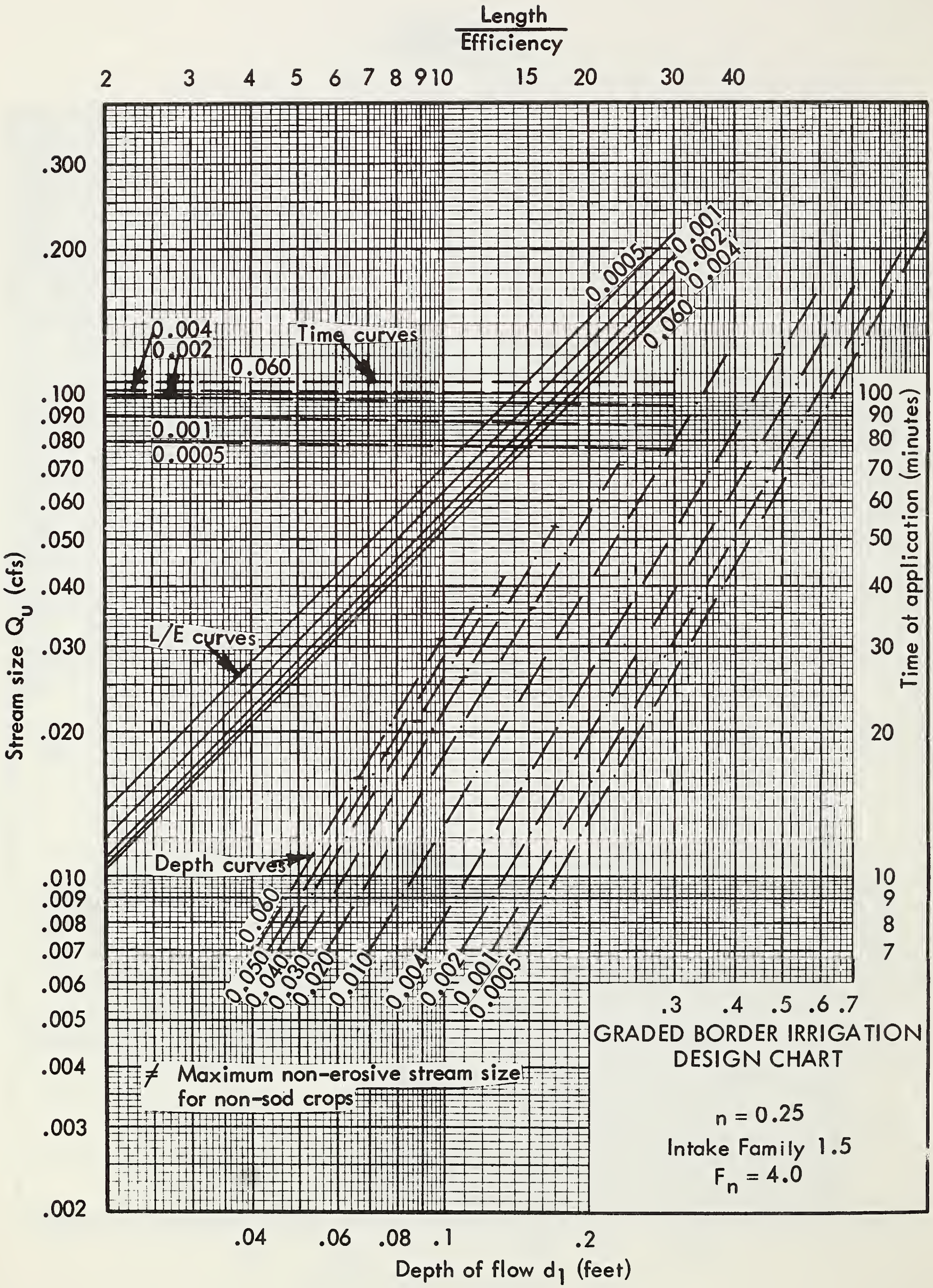


Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
S=0.0005
0.001
0.002
0.004
0.010
0.050
L/E curves
0.010
0.004
0.001
0.050
0.002
0.0005
Time curves
Depth curves
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
≠ Maximum non-erosive stream size for non-sod crops
n =0.25
Intake Family 1.5
F_n = 2.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

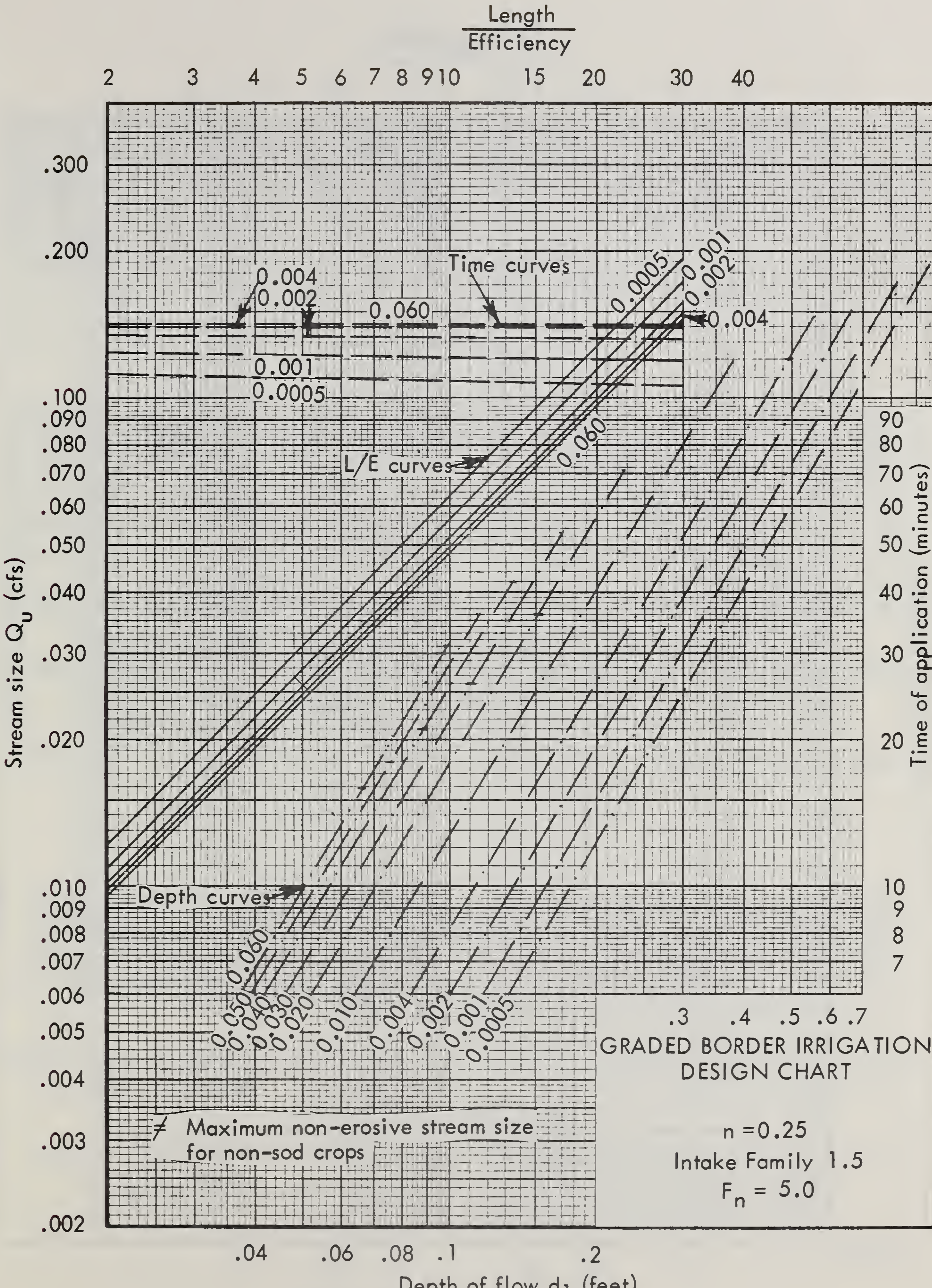


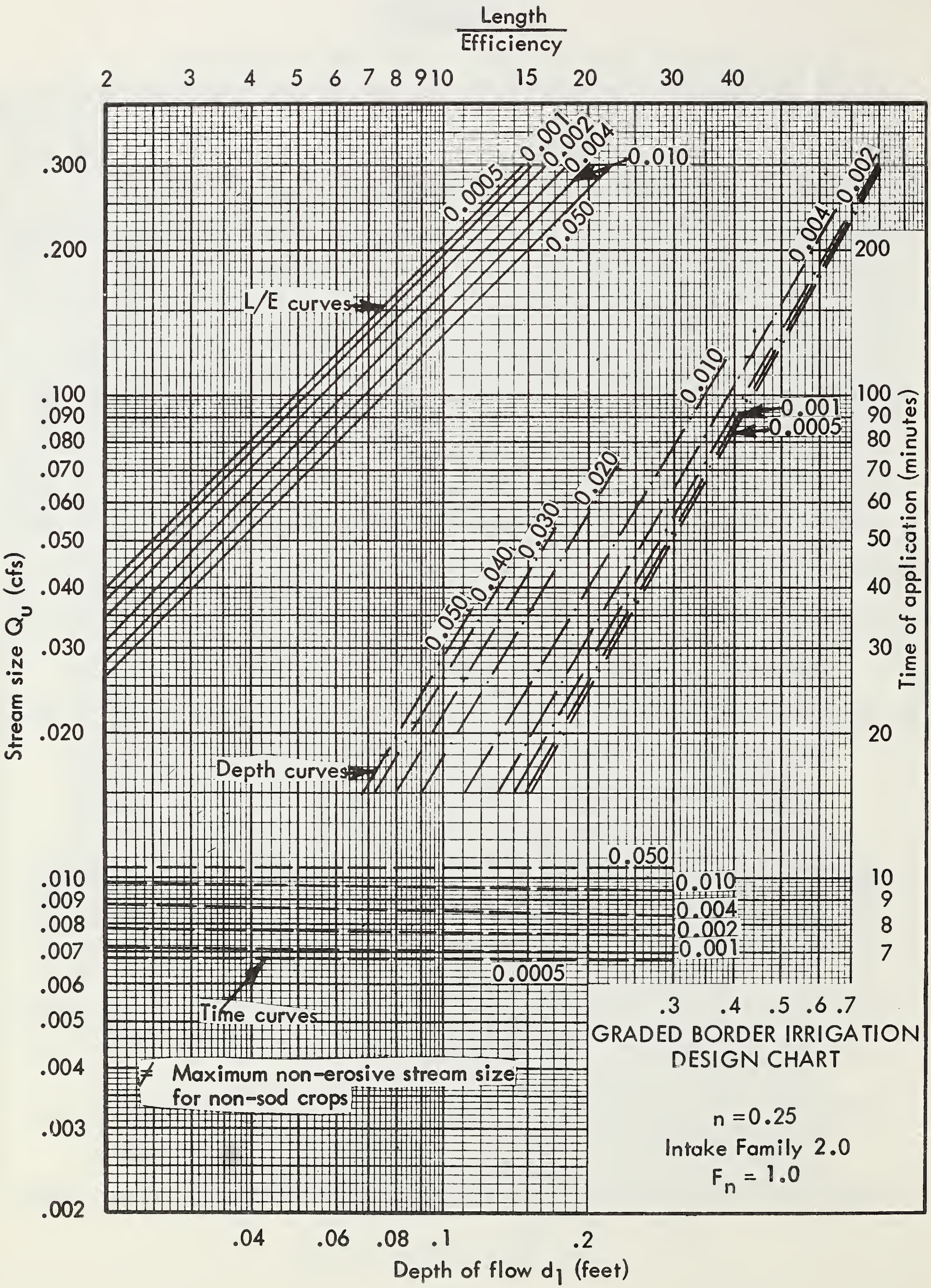
GRADED BORDER IRRIGATION DESIGN CHART

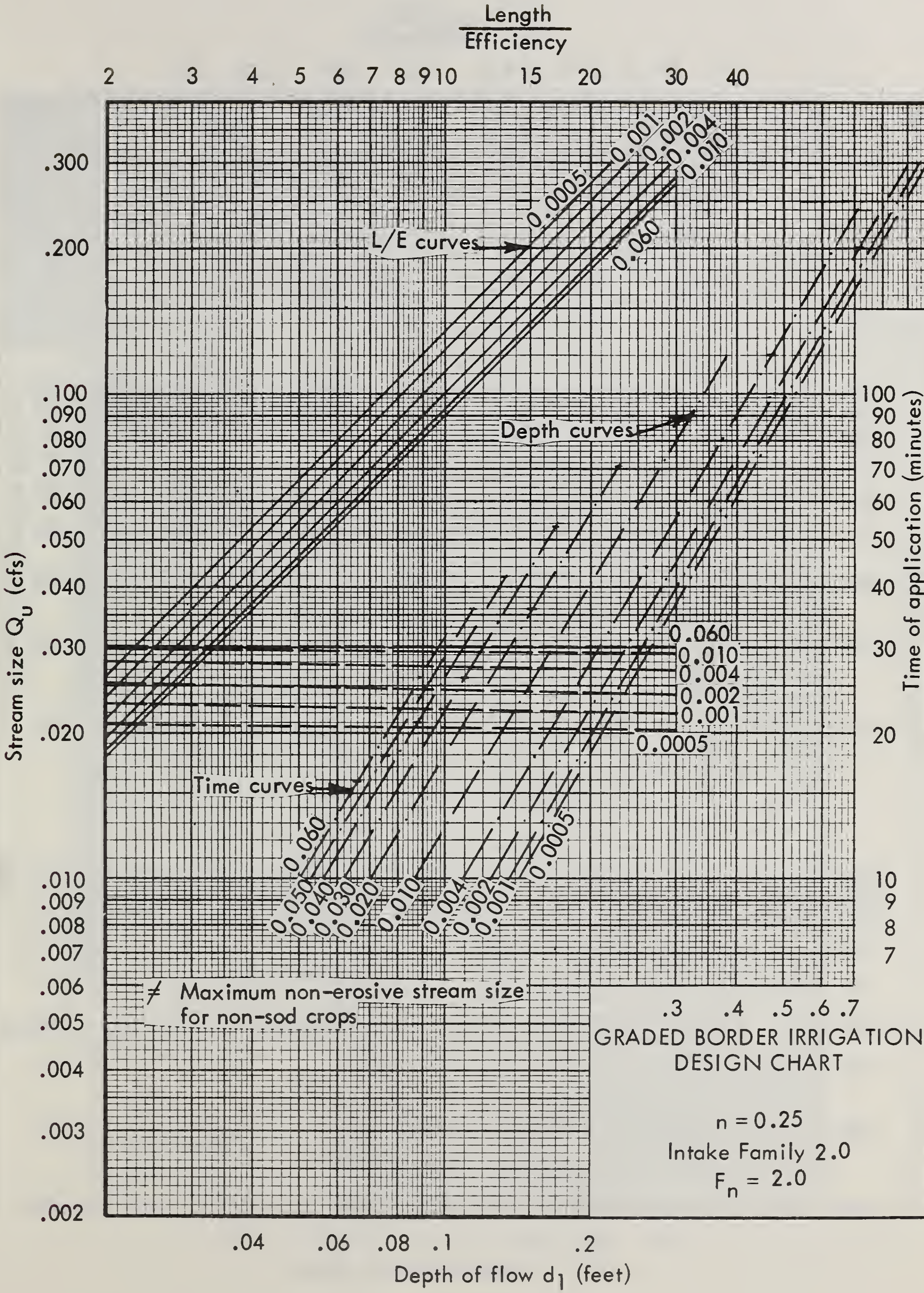
$n = 0.25$
Intake Family 1.5
$F_n = 3.0$



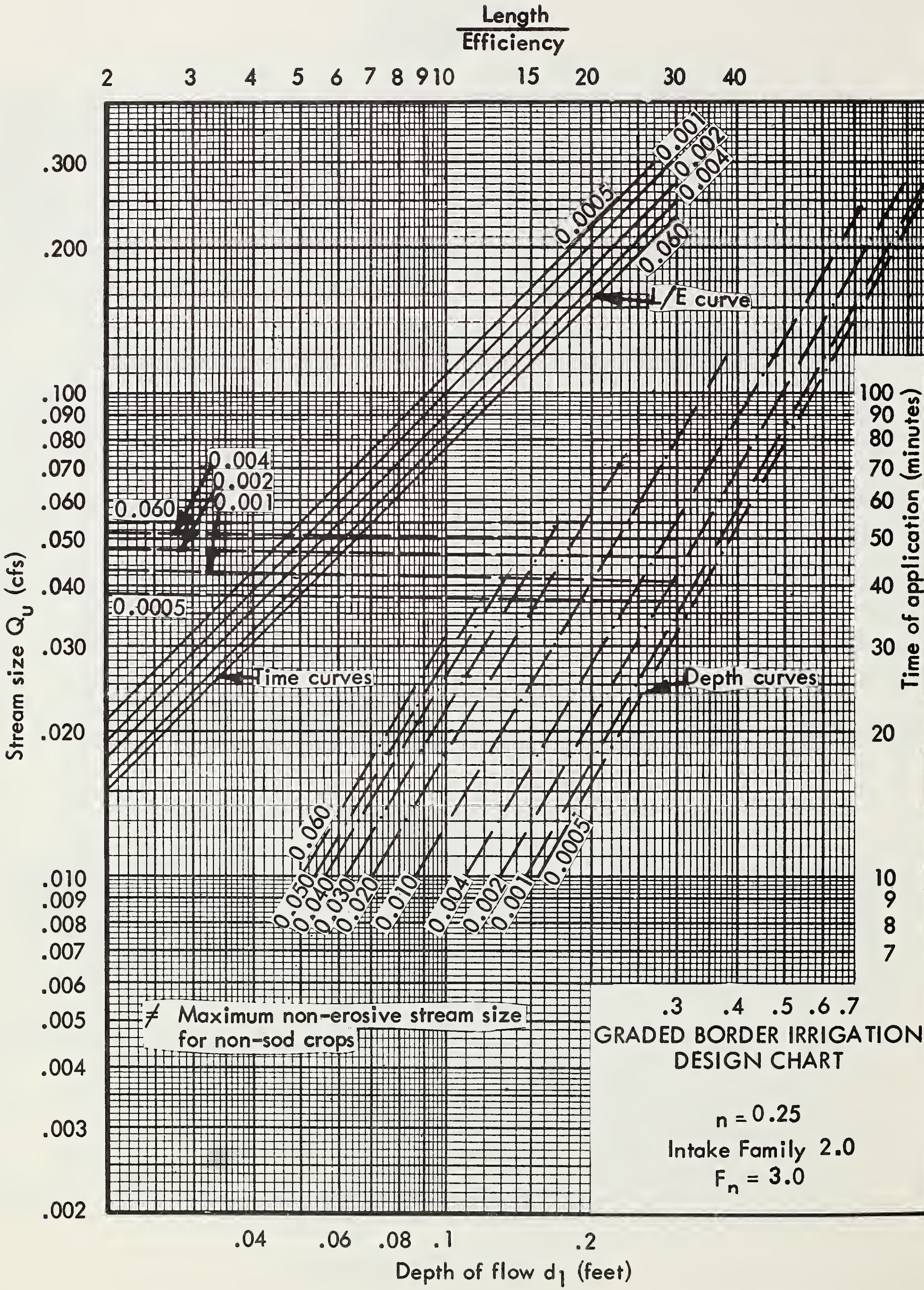
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.004
0.002
0.060
Time curves
0.001
0.0005
0.0005
0.001
0.002
0.004
0.060
L/E curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION
DESIGN CHART
n = 0.25
Intake Family 1.5
$F_n = 4.0$
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

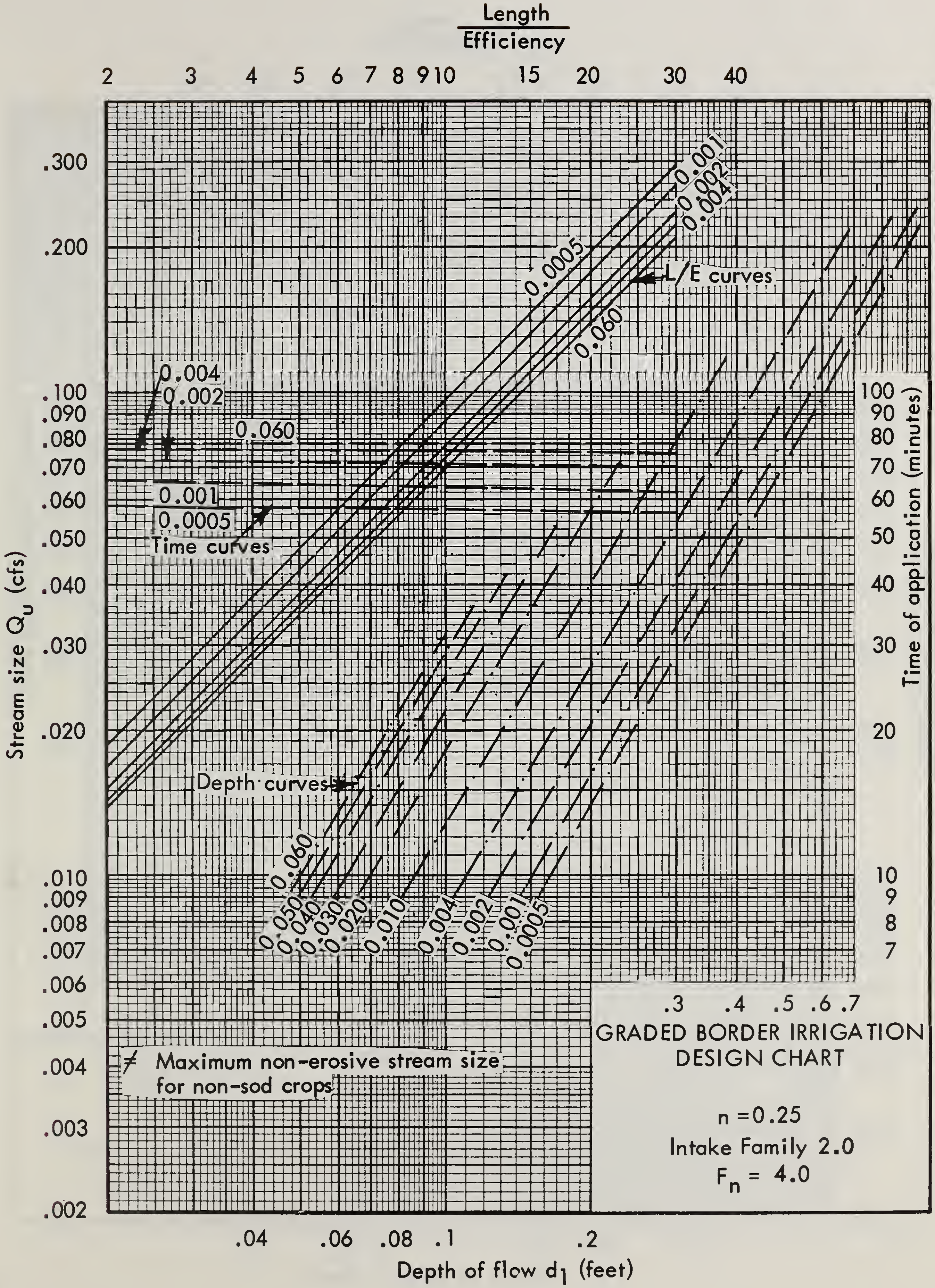

Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
Time curves
0.004
0.002
0.060
0.001
0.0005
0.0005
0.001
0.002
0.004
0.060
L/E curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION
DESIGN CHART
n =0.25
Intake Family 1.5
F_n = 5.0
Maximum non-erosive stream size
for non-sod crops
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
0.0005
0.001
0.002
0.004
0.010
0.050
L/E curves
0.010
0.020
0.030
0.040
0.050
0.004
0.002
0.001
0.0005
Depth curves
0.050
0.010
0.004
0.002
0.001
0.0005
Time curves
≠ Maximum non-erosive stream size for non-sod crops
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 1.0



Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
L/E curves
0.0005
0.001
0.002
0.004
0.010
0.060
Depth curves
0.060
0.010
0.004
0.002
0.001
0.0005
Time curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
≠ Maximum non-erosive stream size for non-sod crops
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 2.0
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
0.001
0.002
0.004
0.0005
0.060
L/E curve
0.004
0.002
0.001
0.060
0.0005
Time curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 3.0

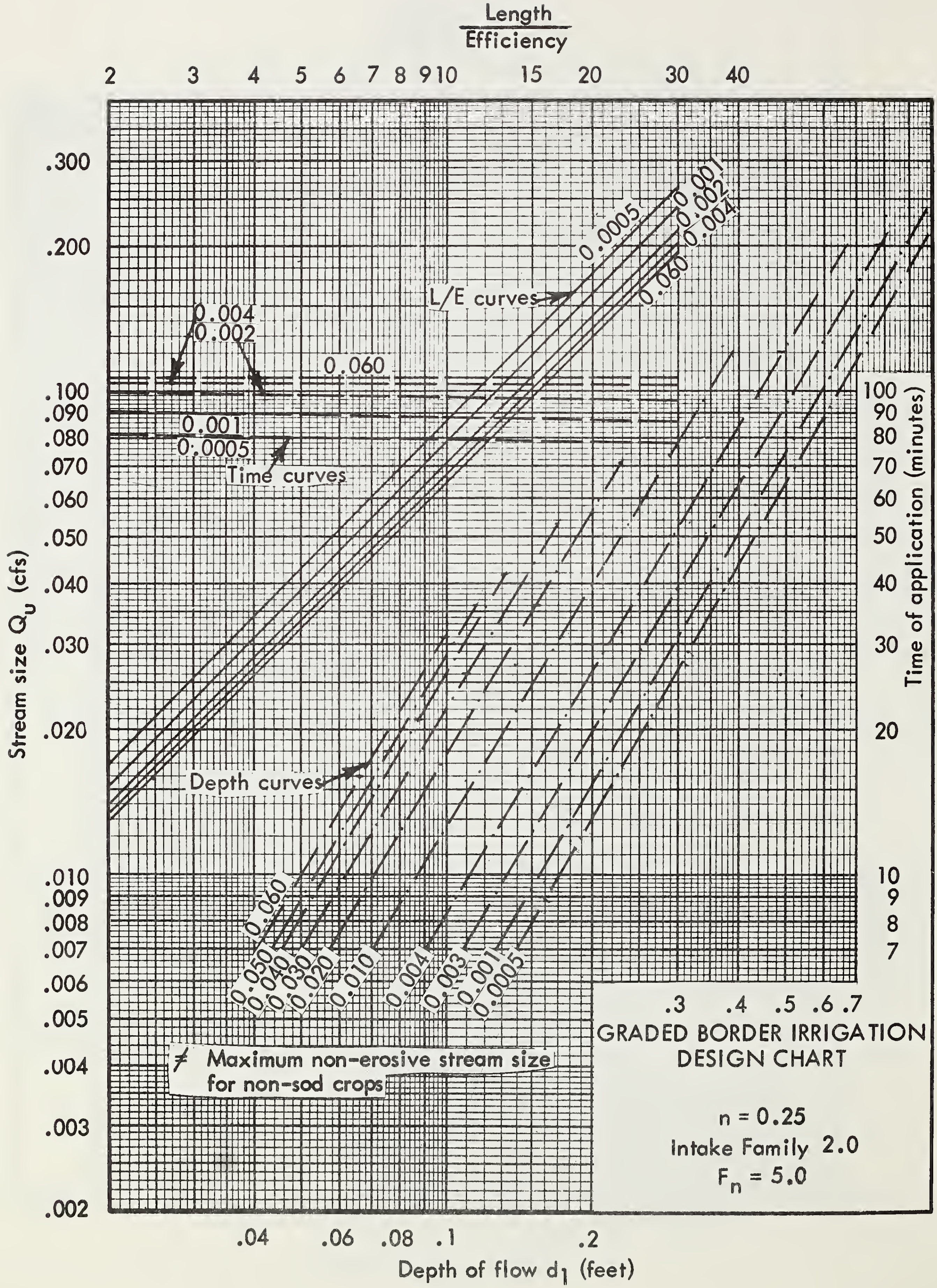


GRADED BORDER IRRIGATION DESIGN CHART

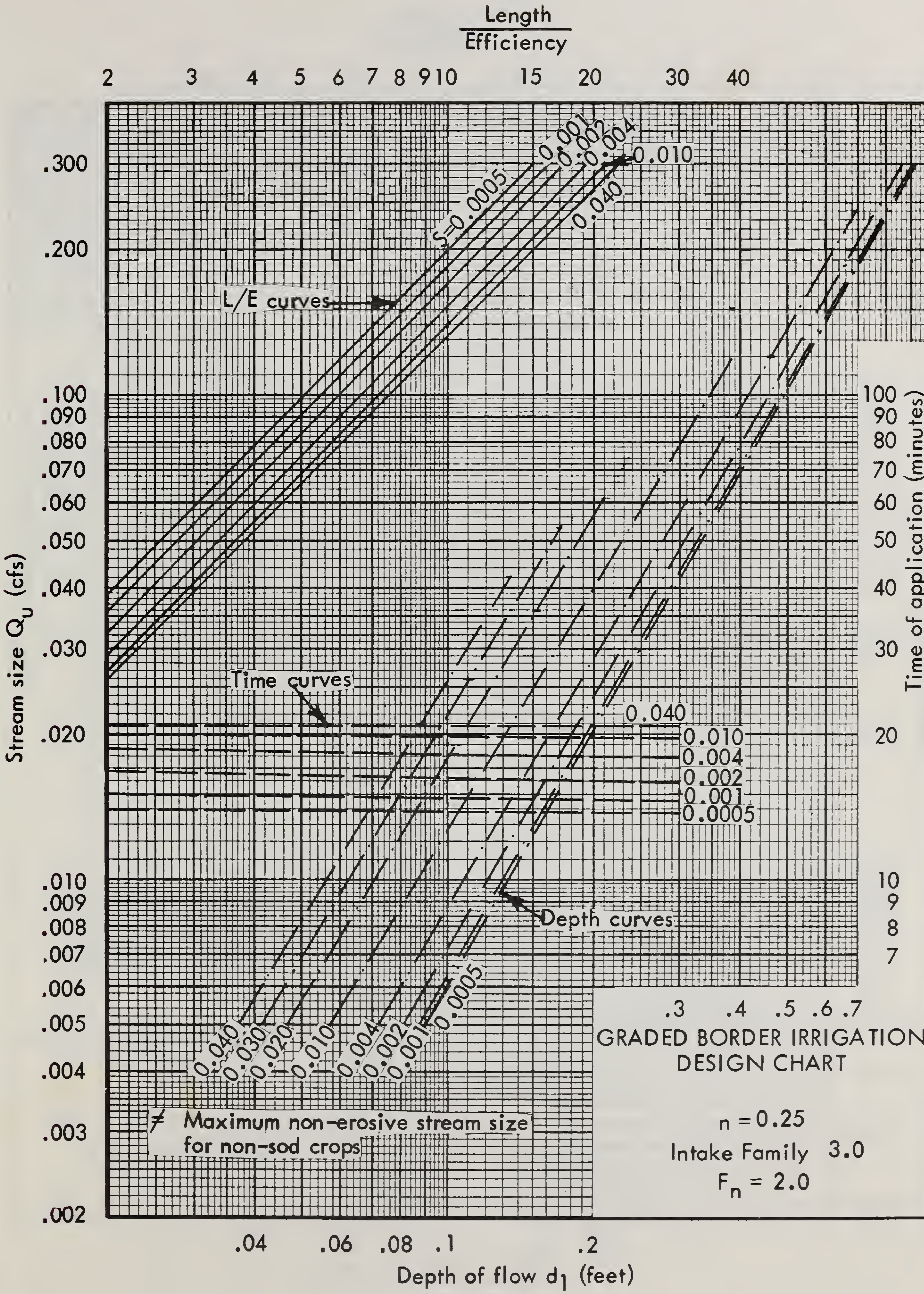
n = 0.25

Intake Family 2.0

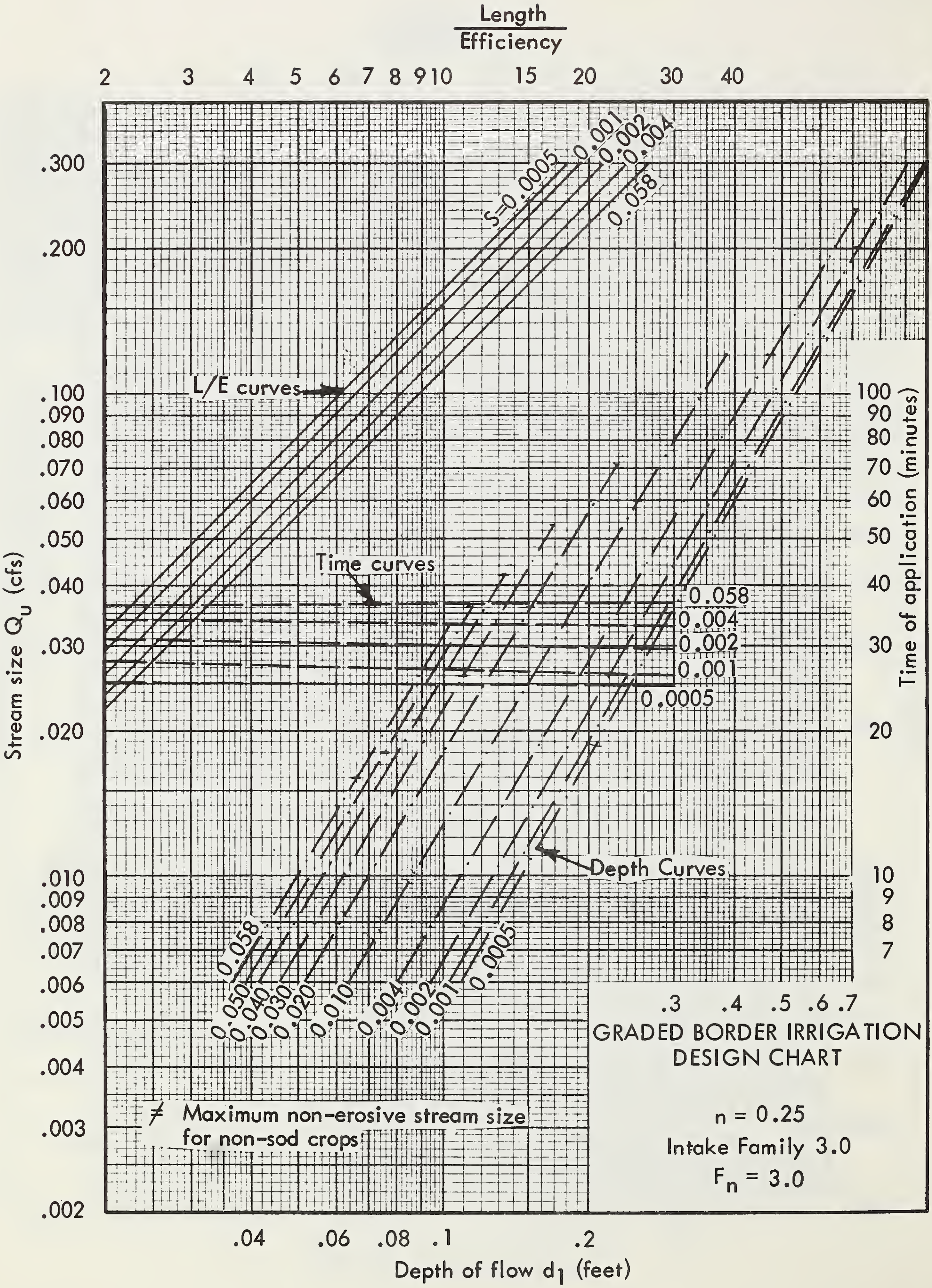
F_n = 4.0



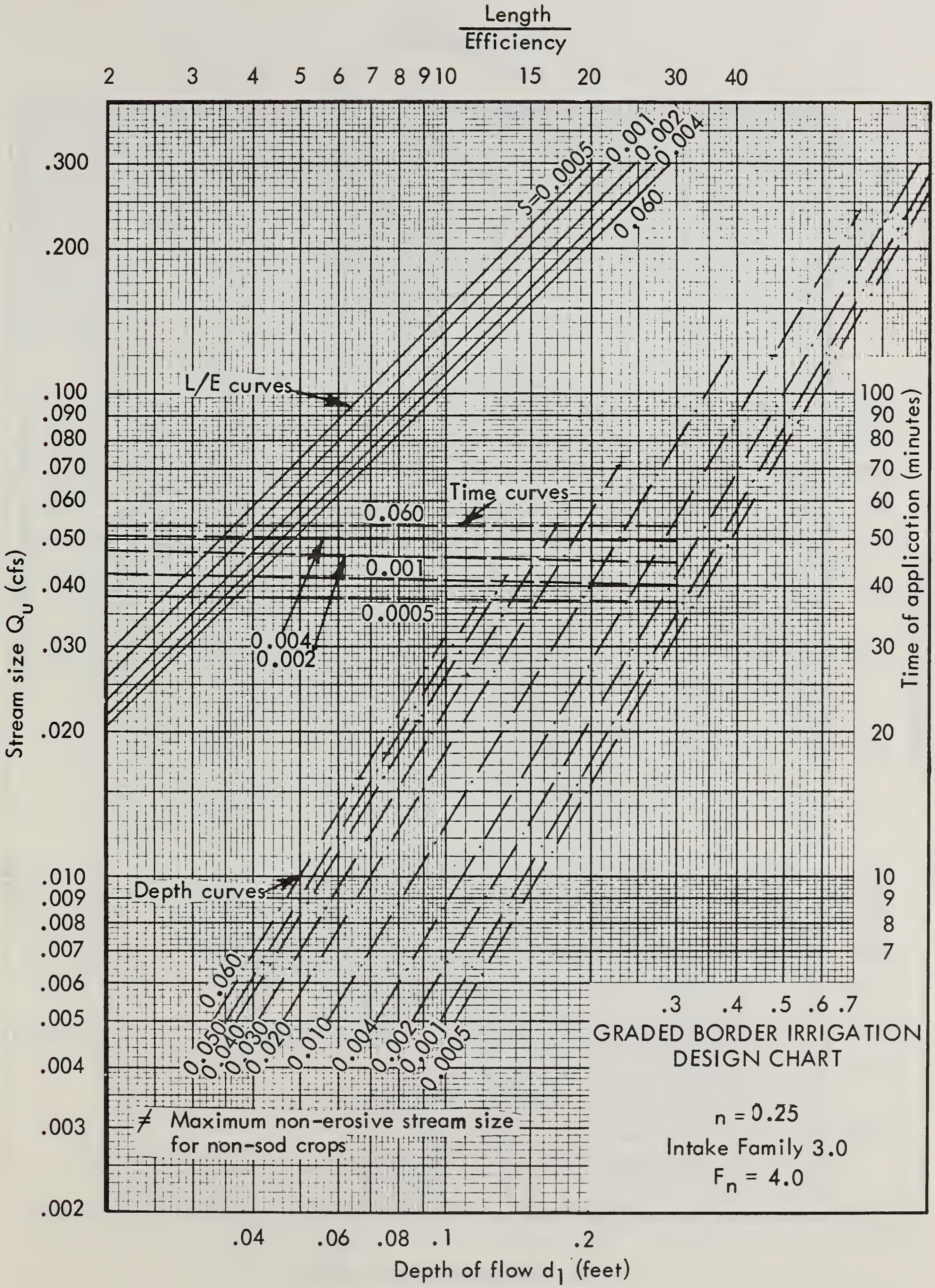
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
L/E curves
0.0005
0.001
0.002
0.004
0.060
Time curves
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.003
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 2.0
F_n = 5.0



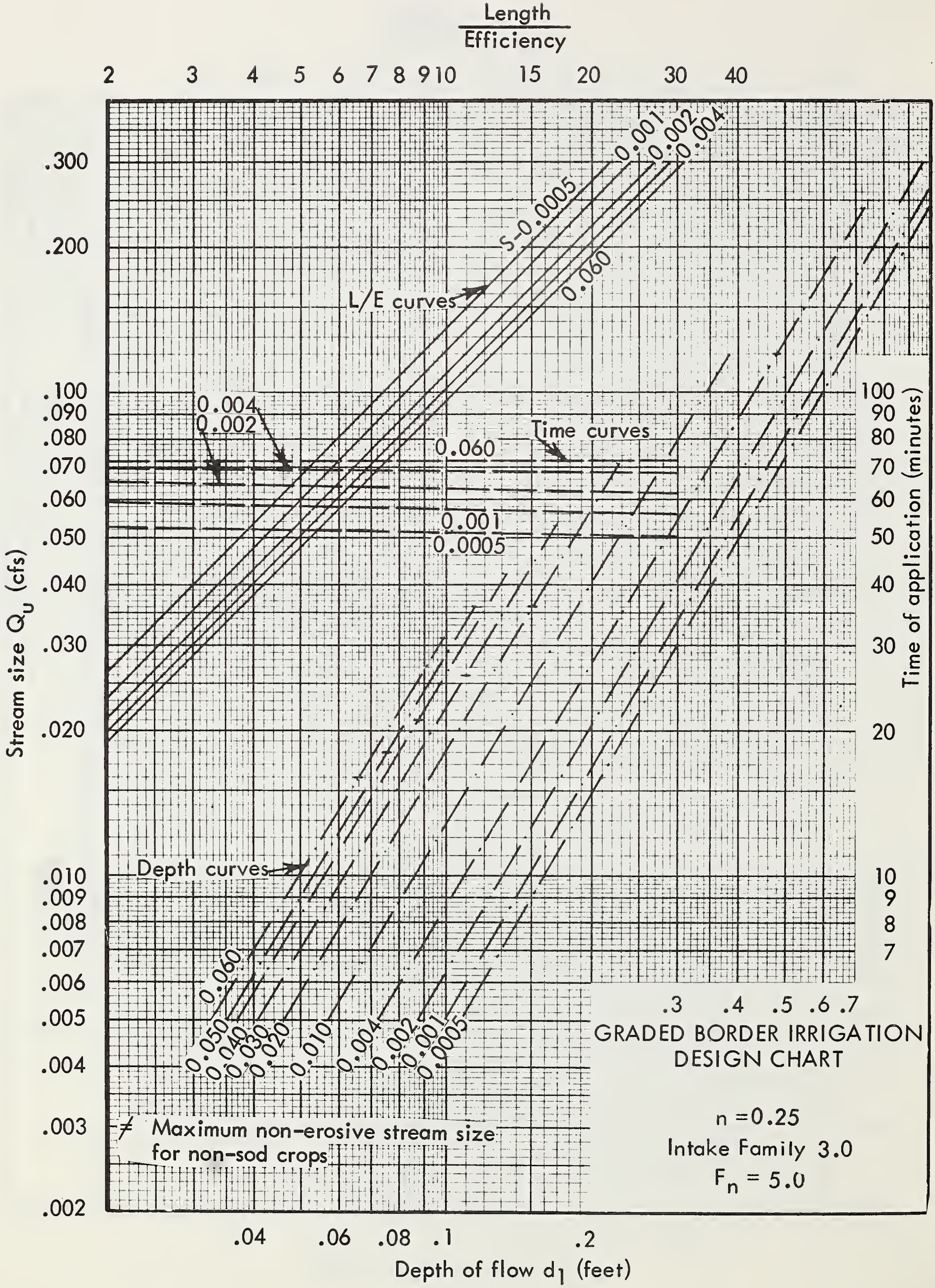
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
L/E curves
S=0.0005
0.001
0.002
0.004
0.010
0.040
Time curves
0.040
0.010
0.004
0.002
0.001
0.0005
Depth curves
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 3.0
F_n = 2.0

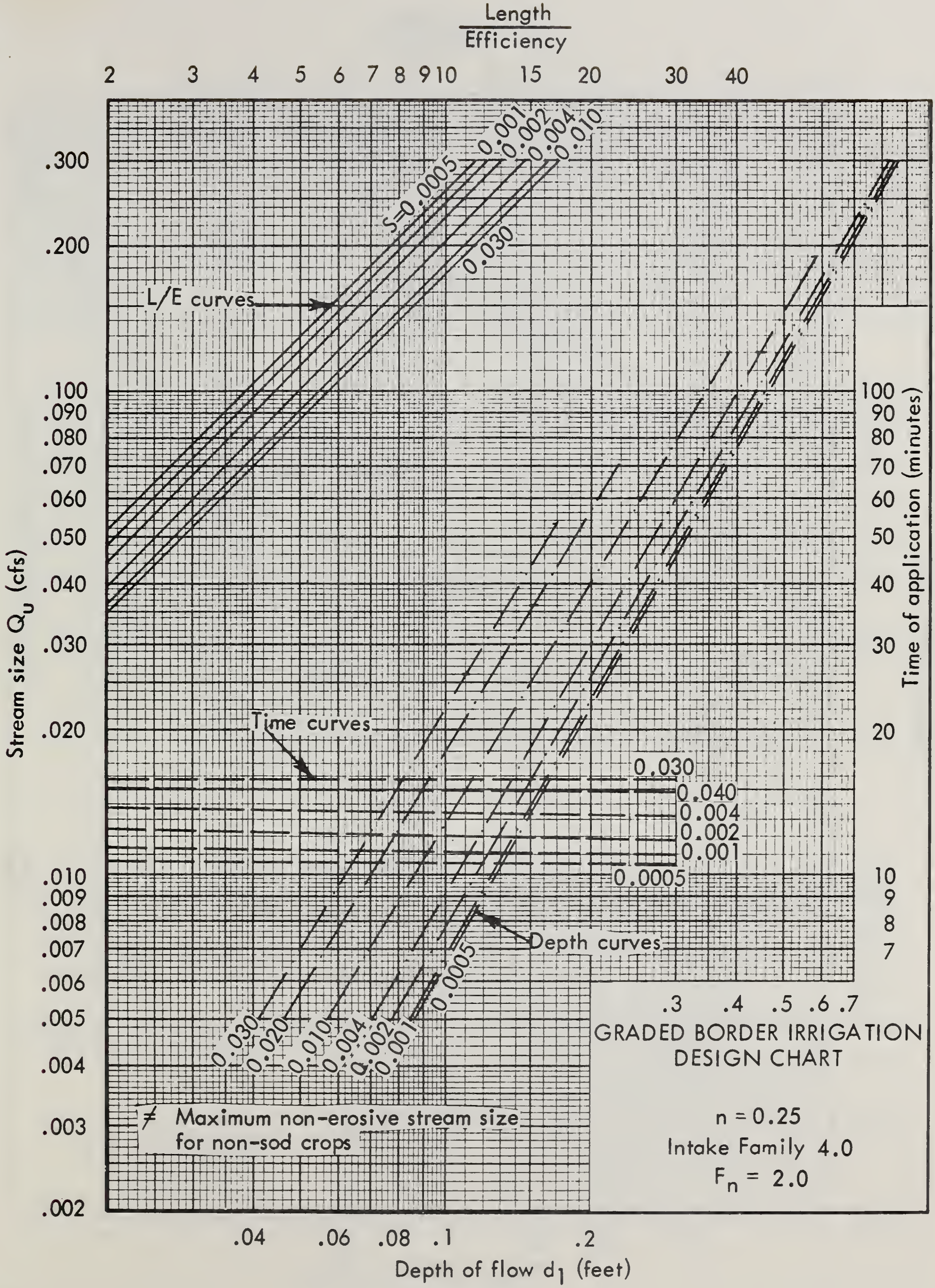


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005 0.001 0.002 0.004 0.058
L/E curves
Time curves
0.058 0.004 0.002 0.001 0.0005
Depth Curves
0.058 0.050 0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
≠ Maximum non-erosive stream size for non-sod crops
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 3.0
F_n = 3.0

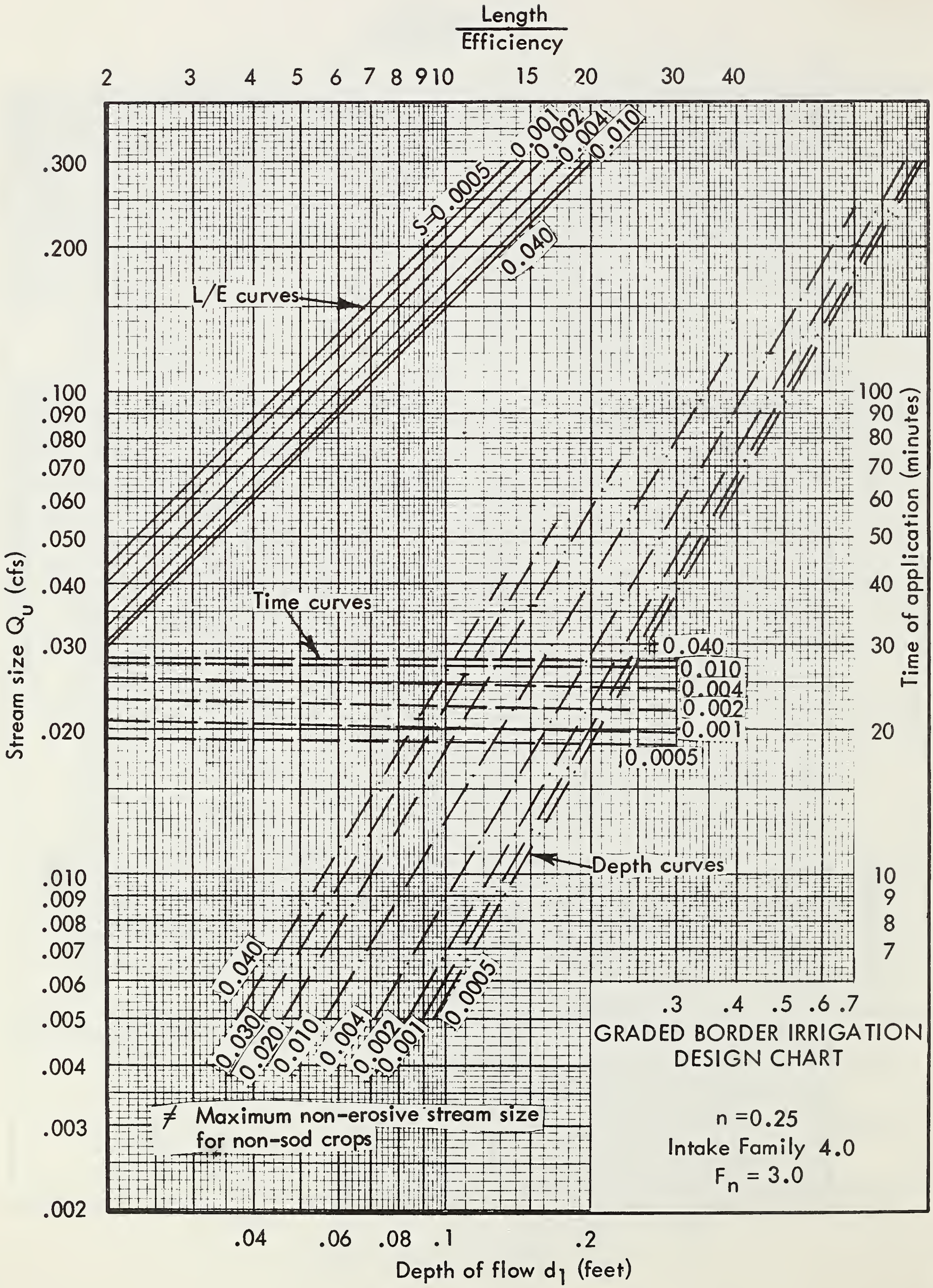


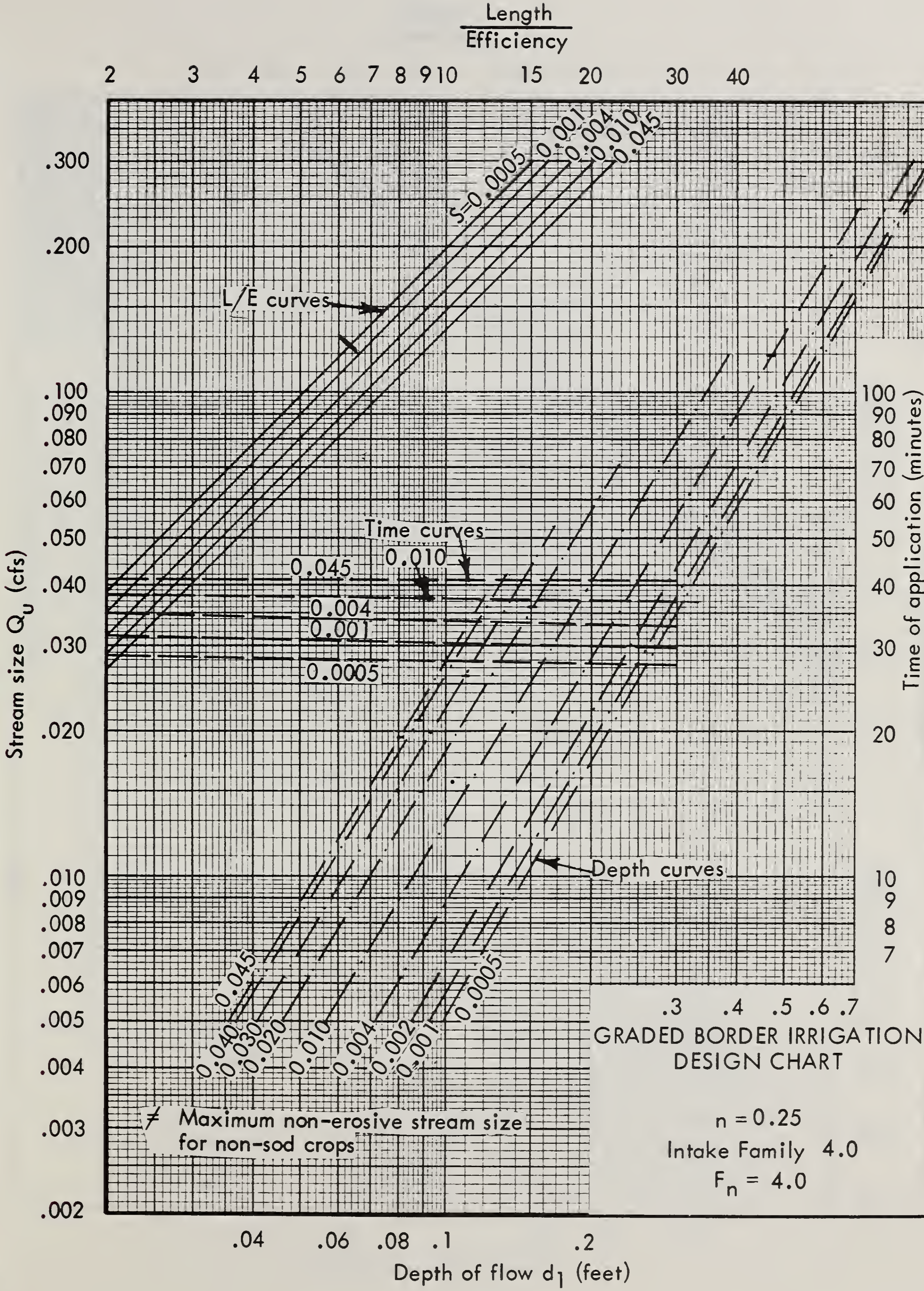
Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005
0.001
0.002
0.004
0.060
L/E curves
Time curves
0.060
0.001
0.0005
0.004
0.002
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 3.0
F_n = 4.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
100
90
80
70
60
50
40
30
20
10
9
8
7
Time of application (minutes)
S-0.0005
0.001
0.002
0.004
0.060
L/E curves
0.004
0.002
0.060
Time curves
0.001
0.0005
Depth curves
0.060
0.050
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
.3 .4 .5 .6 .7
GRADED BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 3.0
F_n = 5.0
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)

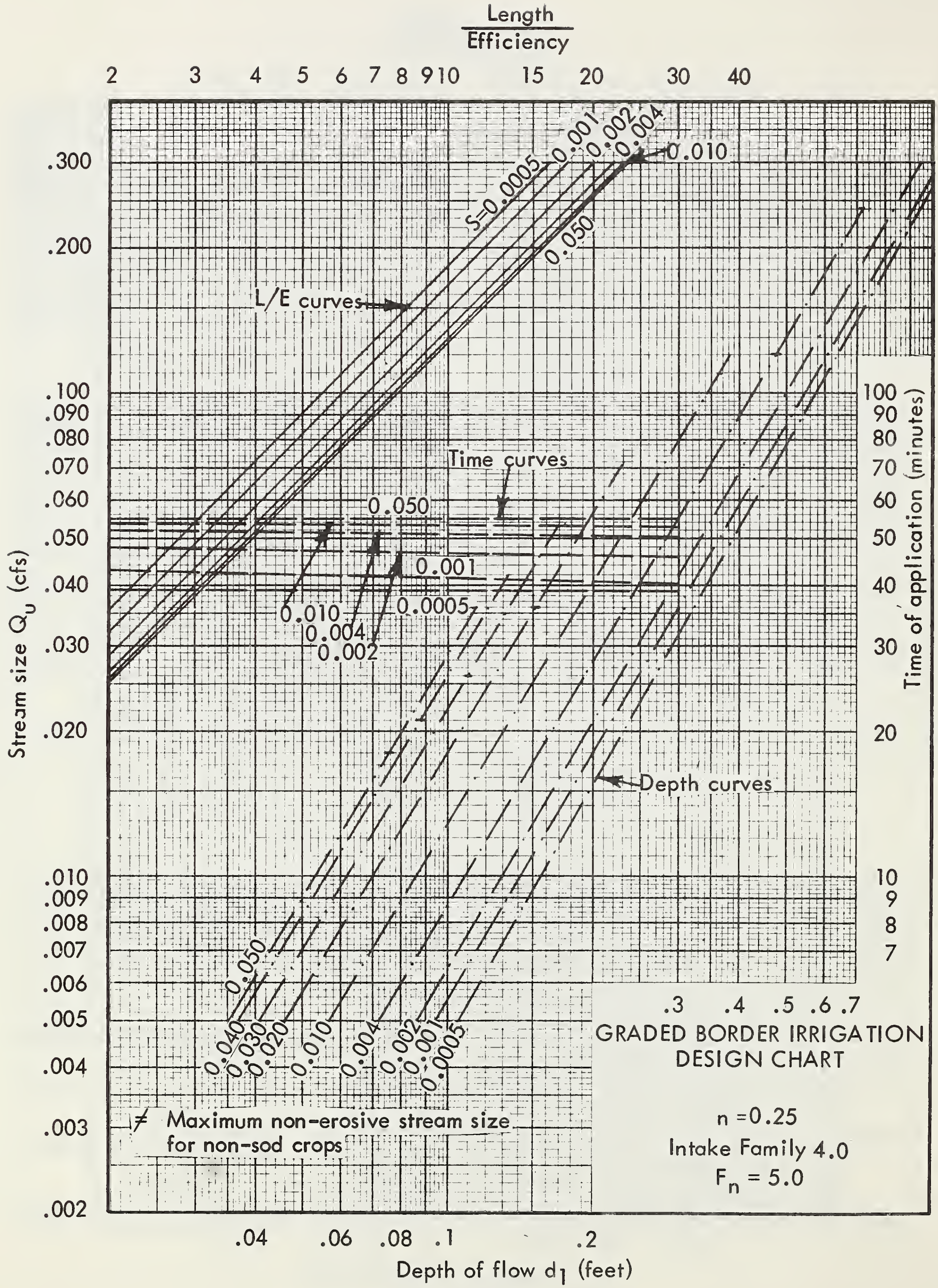


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005 0.001 0.002 0.004 0.010
0.030
L/E curves
Time curves
0.030
0.040
0.004
0.002
0.001
0.0005
Depth curves
0.030 0.020 0.010 0.004 0.002 0.001 0.0005
≠ Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 2.0


Length
Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005
0.001
0.002
0.004
0.010
0.040
L/E curves
Time curves
Depth curves
.300
.200
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
.009
.008
.007
.006
.005
.004
.003
.002
Stream size Q_u (cfs)
100 90 80 70 60 50 40 30 20 10 9 8 7
Time of application (minutes)
0.040
0.010
0.004
0.002
0.001
0.0005
0.040
0.030
0.020
0.010
0.004
0.002
0.001
0.0005
≠ Maximum non-erosive stream size for non-sod crops
.04 .06 .08 .1 .2 .3 .4 .5 .6 .7
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n =0.25
Intake Family 4.0
F_n = 3.0



Length / Efficiency
2 3 4 5 6 7 8 9 10 15 20 30 40
S=0.0005 0.001 0.004 0.010 0.045
L/E curves
Time curves
0.045
0.010
0.004
0.001
0.0005
Depth curves
0.045
0.040 0.030 0.020 0.010 0.004 0.002 0.001 0.0005
Maximum non-erosive stream size for non-sod crops
Stream size Q_u (cfs)
.300 .200 .100 .090 .080 .070 .060 .050 .040 .030 .020 .010 .009 .008 .007 .006 .005 .004 .003 .002
Time of application (minutes)
100 90 80 70 60 50 40 30 20 10 9 8 7
.3 .4 .5 .6 .7
.04 .06 .08 .1 .2
Depth of flow d_1 (feet)
GRADED BORDER IRRIGATION DESIGN CHART
n = 0.25
Intake Family 4.0
F_n = 4.0



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